SYMPOSIUM ON PLASTIC SURGERY

Vol. 15 JANUARY, 1944 No. 1

SURGERY

A Monthly Journal Devoted to the Art and Science of Surgery

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CONTENTS

Symposium on Plastic Surgery

Planning the Reconstruction. Ferris Smith, M.D., Grand Rapids, Mich. ---- 1

Treatment of Battle Casualties and Street or Industrial Wounds of the Face. V. P. Blair, M.D., St. Louis, Mo. ---- 16

Early Treatment of Gunshot Wounds of the Face and Jaws. V. H. Kazanjian, M.D., Boston, Mass. ---- 22

Some Deformities of the Face and Their Correction. Warren B. Davis, M.D., Sc.D., F.A.C.S., Philadelphia, Pa. ---- 43

The Repair of Bony and Contour Deformities of the Face. Robert H. Ivy, M.D., Philadelphia, Pa. ---- 56

Evaluation of Pedicle Flaps Versus Skin Grafts in Reconstruction of Surface Defects and Scar Contractures of the Chin, Cheeks, and Neck. Gustave Aufricht, M.D., New York, N. Y. ---- 75

The Vascular Prerequisites of Successful Skin Grafting. Kurt Lange, M.D., New York, N. Y. ---- 85

Fibrin Fixation of Skin Transplants. R. T. Tidrick, M.D., and E. D. Warner, M.D., Iowa City, Iowa ---- 90

The Treatment of Burns and Other Extensive Wounds With Special Emphasis on the Transparent Jacket System. Beverly Douglas, M.D., Nashville, Tenn. 96

Early Treatment of Burns. A. W. Farmer, M.D., Toronto, Can. ---- 144

Repair of the Burned Hand. George Warren Pierce, M.D., E. H. Klabunde, M.D., and D. Emerson, M.D., San Francisco, Calif. ---- 153

Plastic Repair of Extensor Hand Contractures Following Healed Deep Second Degree Burns. Paul W. Greeley, M.D., Oakland, Calif. ---- 173

Rehabilitation Following Severe Burns. Bradford Cannon, M.D., Boston, Mass. 178

Free Transplantation of the Nipples and Areolae. William Milton Adams, M.D., Memphis, Tenn. ---- 186

Simplified Method of Rotating Skin and Mucous Membrane Flaps for Complete Reconstruction of the Lower Lip. Neal Owens, M.D., New Orleans, La. ---- 196

Editorial

A Plea for a Campaign to Reduce Burn Hazards. Neal Owens, M.D., New Orleans, La. ---- 207

Book Reviews

Book Reviews ---- 210

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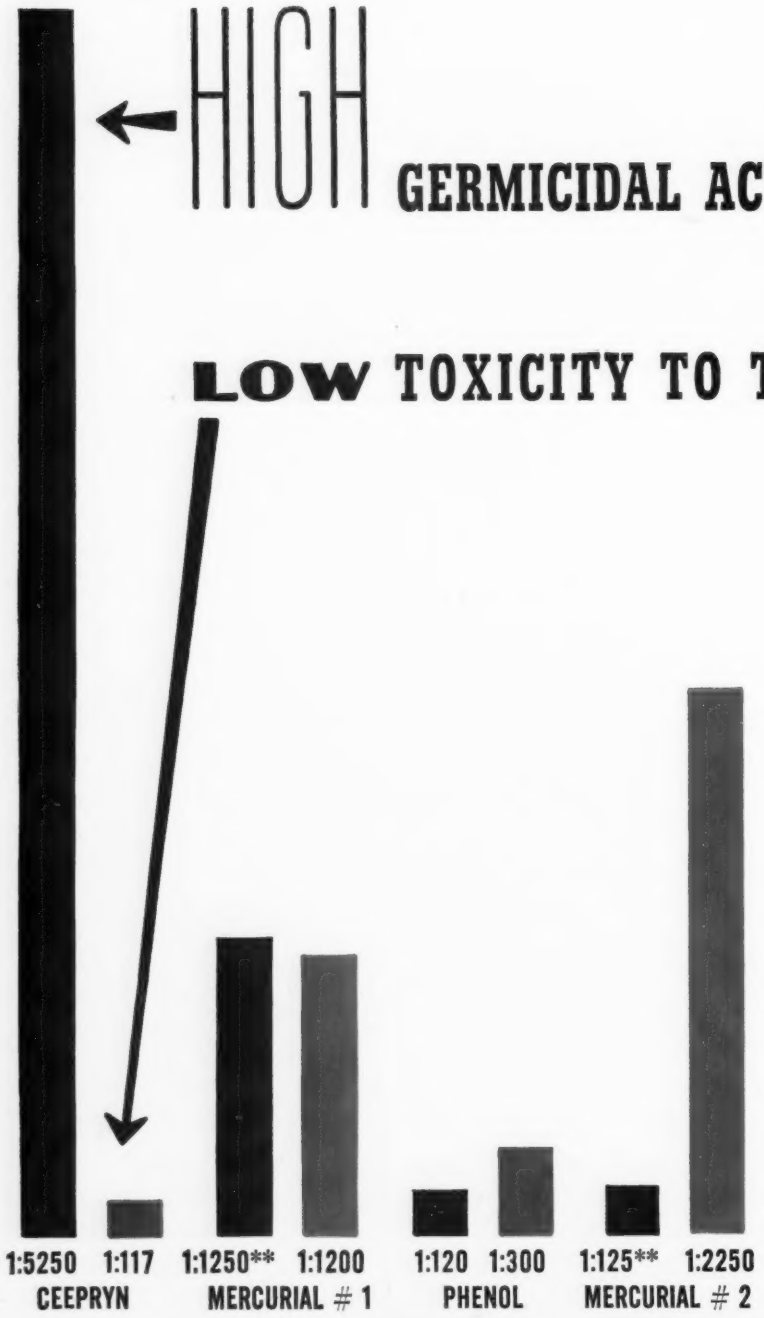

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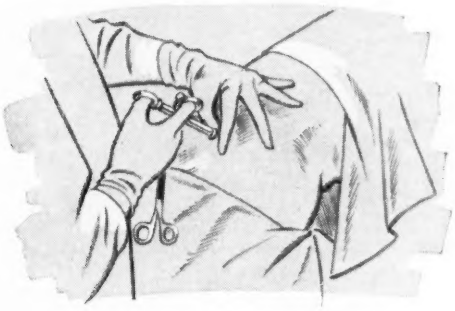

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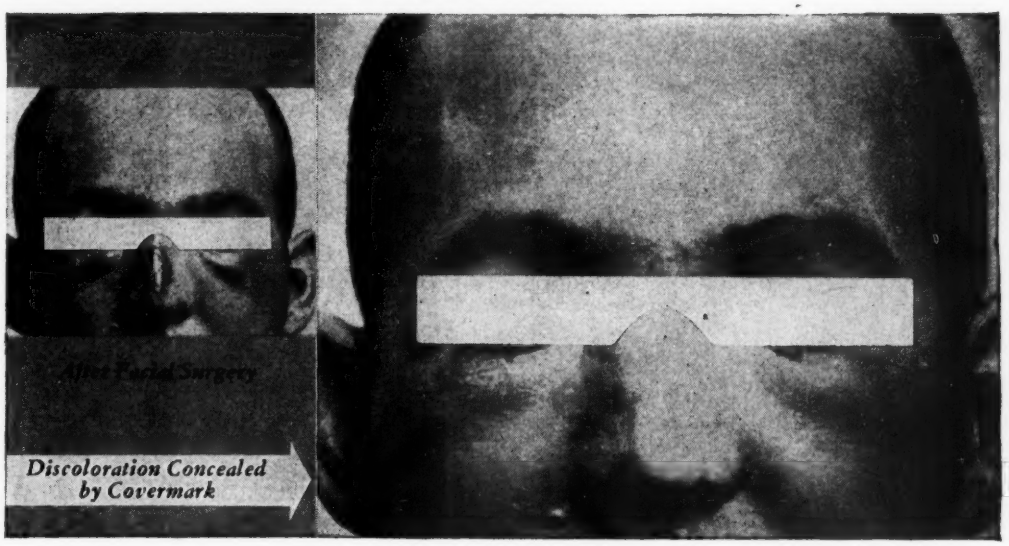

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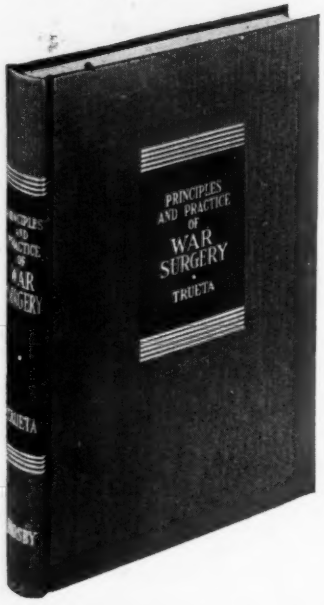

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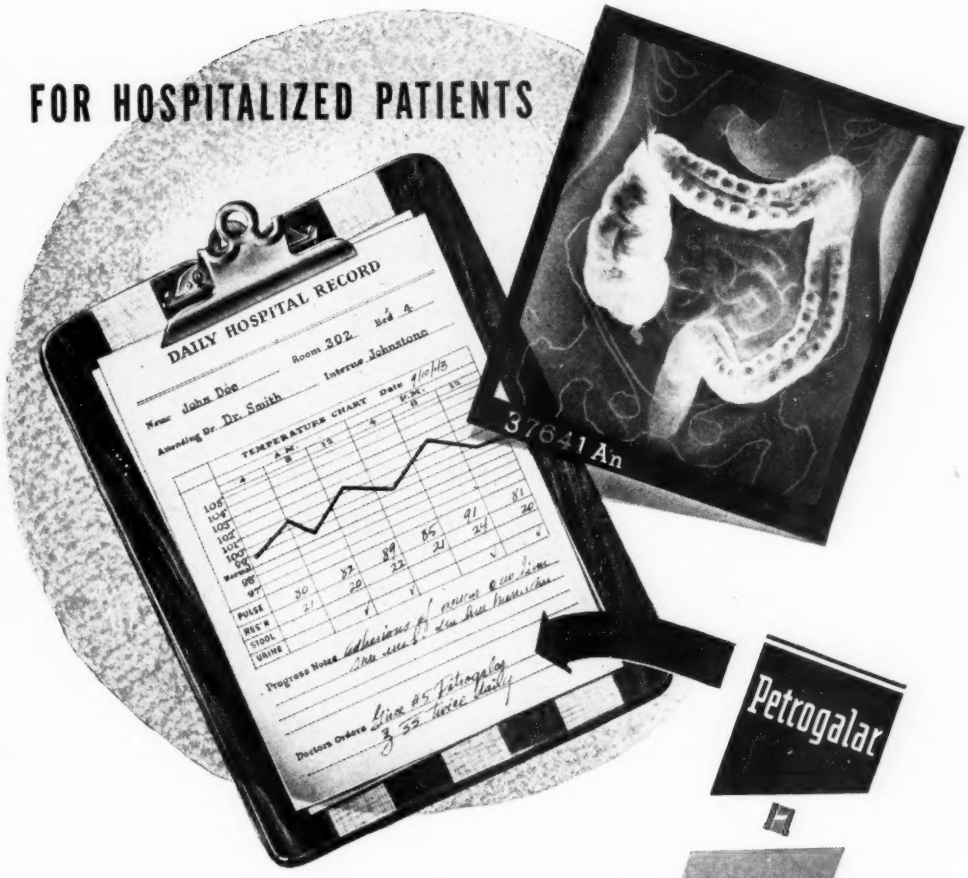

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SURGERY

VOL. 15 JANUARY, 1944 NO. 1

Original Communications

Symposium on Plastic Surgery

PLANNING THE RECONSTRUCTION

FERRIS SMITH, M.D., GRAND RAPIDS, MICH.

THE purpose of all reconstructive surgery is the restoration of the part or area to normal or as near to normal as possible. This should include both function and cosmesis. The relative importance of these two objectives varies with the area repaired.

All of the required materials for the repair are available in the patient's body and their use, with two exceptions, cartilage and cornea, are vital to a successful ultimate outcome.

Since the principles of reconstruction of all body surfaces, whether the result of trauma, burns, or congenital defects, are the same and those of the face and neck most exacting in meeting the dual purpose of the effort, this discussion will be devoted to the latter area.

The fundamental principles of obtaining, transferring, and utilizing the various covering and supporting tissues were fully described before World War I, but this isolated literature was not collected, correlated, and appraised for the use of the surgeon. The reconception and employment of methods long since discarded as unsound was a consequence before standards were established. Some procedures of great value were neither generally known nor utilized at all. Many of the cardinal principles had been described for centuries and all had suffered vogues or periods of surgical popularity much as the styles in clothing.

The literature of antiquity relates the extensive practice of tissue transplantation by the Egyptians as far back as 3500 B.C. and reveals that both flap and grafting operations were well known to the Hindu

Received for publication, June 8, 1943.

people. The progress of tissue transplantation, like other branches of medicine and surgery, followed the rise and fall of empires.

Galen (A.D. 130-210), the last great physician of antiquity, advised the removal of all scar tissue about a defect and the approximation of the wound margins with sutures. He described minutely the repair of defects about the mouth, nose, and ears.

Shortly after his death, the Barbarians plunged all Europe into the period known as the Dark Ages. The light of surgical knowledge guttered and nearly extinguished, and what was known of this subject was forgotten.

The revival of learning in the fifteenth and sixteenth centuries resurrected the art of transplanting skin flaps. Branca (1442) reintroduced the Indian method of using flaps from the forehead to repair defects of the nose and face. This procedure, with its modern technical safeguards and supplements, was popularized during World War I and remains as one of a triad of procedures most utilized about the world today. Antonius, Branca's son, resorted to the use of flaps from the arm to prevent additional scarring of the face. He was concerned with a better cosmetic result. This same conception should have its counterpart in the planning and execution of such surgery today. He had in this thought the seed which has grown through the centuries into the second of the triad of procedures for facial repair most popularized and practiced today.

Tagliacozzi is generally credited with the origin of the arm flap. He did most to develop and popularize it among his confreres. The operation, however, died with him. The clergy bitterly accused him of "interfering with the handiwork of God" and attributed his success to the "Evil One."

The University of Paris put a band on all such types of surgery toward the end of the eighteenth century and seemed to dispose of the practice of tissue transplantation forever. It was fortunate, however, that a report from India on a rhinoplastic operation published in a popular magazine in England aroused a new interest in the feasibility of the procedure. Surgeons in England, America, France, and Germany made use of the procedure during the subsequent fifty years.[1]

The art of free tissue transplantation, however, lay dormant for sixteen centuries. It was resurrected by Riverdin, a Swiss surgeon working in Paris, in 1869.[2] He demonstrated the successful transplantation of living skin to a granulating surface by grafting some small bits of epidermis on the raw surface of a thumb. He was a "prophet without glory in his own country" and it remained for Pollock of London to establish the procedure. Riverdin reported again in 1872, stating that he now took a portion of the dermis with his graft.[3] Riverdin thus

resurrected the third of the triad of favored modern procedures. This method remains popular with many general surgeons at the present time, despite the fact that it no longer has a proper place in surface repair. It was not modified until Davis described his small, deep graft in 1940.[4]

It was observed, meanwhile, that the limited proliferative power of a single graft necessitated numerous grafts for the repair of any sizable surface, that grafting a bleeding surface is usually unsuccessful, that the papillary layer is essential, and that epithelium will grow most rapidly over the least distance to other growing epithelium.

Ollier (1872) first, and then Thiersch (1874) described a different method to overcome these disadvantages. The former wrote in 1872, "I use large grafts including not only superficial layers of the skin but part of the derma."[5] This procedure was immediately accepted and has enjoyed a greater popularity and usefulness than any other until Blair and Brown described a thicker graft, which they termed "split skin," in 1929.[6] It was observed early in its use that this graft did not control scar contraction, that it was not serviceable on pressure and flexor surfaces, and that it usually suffered pigmentation. These objections are largely common to the Blair-Brown modification.

These criticisms led to the revival of the Indian method of free full-thickness grafting by Wolfe in 1875.[7] This graft contracts little, is soft, pliable, largely resistant to pressure, and suffers less pigmentation than the other types. On the other hand, its use is limited to surface parts which are clean and can be immobilized. The conditions and technique of obtaining and growing it are much more exacting than the others.

These objections revived interest in the Indian and Italian flap operations. Maas, in 1884, described the possibilities and technique of these methods so clearly that they underwent little change until the last World War.[8] Many of the variations in the use of pedicled flaps were described by 1905.

This sketchy recital of the painfully slow, hectic evolution of the modern graft and pedicled flap through 5,000 years brings us to the period of World War I. It is an evolution profoundly influenced by the growth and death of learning in the rise and fall of empires; by the narrow, lethal effect of the secular control of scientific development, and by the skepticism and dicta of egotistic men.

The recognition of the necessity for epithelial lining of flaps covering cavities and for supporting structure, either autogenous or prosthetic, crystallized in the same but a more limited manner. It required centuries to recognize that the raw surface of the flap covering a cavity contracted because of scar formation and that epithelial protection is

necessary to prevent it! The essential value of supporting framework was recognized early in this long period of evolution; the anatomic and physiologic principles in providing it have long since been established by observation of trial and error, but these principles are not universally followed today. All types of foreign substances have been advocated and discarded through the centuries, yet new and old ones continue to be introduced. The surgeon frequently refuses to recognize the fate of foreign bodies.

Two important and essential principles of repair were ignored or given scant attention during World War I and have received little more consideration since, except in isolated quarters. I refer to the Z plastic procedure and multiple excision. The former was first described by Denonvilliers,[9] in 1856, and the latter by Morestin,[10] in 1915. Z plastic procedure has been discussed in the literature occasionally since that time, as a method of correcting scar contractures. It has had wide employment in this connection, but numerous other possibilities of its usefulness, both alone and in combination with other principles, appear to be unappreciated.

Davis called attention to the great value and varied uses of multiple excision in 1929.[11] Davis and Kitlowski,[12] in an article published in 1939 dealing with the usefulness of Z plastics for the correction of scar contractures, state, "We find that there are many who do not understand the procedure at all, or realize its usefulness."

"Multiple excision" is the term utilized by Morestin to describe a method of correcting a surface deformity by repeated partial removal and the replacement of the excised portion with normal tissue from the border of the defect. The extent of each removal and replacement is determined by the amount of skin and subcutaneous tissue which can be shifted into the area at each procedure. Repeated procedures of this sort at proper intervals are possible because the skin subsequently returns to its normal tension and elasticity. It is a most important and useful procedure alone or employed in conjunction with other methods of repair.

The experience of the last war stimulated a universal interest in reconstructive surgery, crystallized and standardized many procedures, contributed methods and applications which revolutionized plastic procedure and increased greatly the possibility and variety of useful repair. Among these are the "tubing" of the pedicle of a flap to reduce the possibilities of infection and to permit the safe transference of tissue from a distance.

The enormous demands on the surgeon and his individual lack of experience resulted in the general employment of methods which masked a loss, restored function to a large degree, and left much to be desired from a cosmetic standpoint in many instances. This has continued to

be more or less true. The last quarter century seems to mark another period when certain procedures have enjoyed an almost exclusive vogue regardless of their desirability, while others equally or more important are practically ignored.

The influence of the tubed pedicle on the development of reconstructive surgery during this period has been profound. This, and the availability of rotated flaps of forehead skin for repair of the nose, eyelid, or cheek and the use of free skin grafts has largely dominated the conception and practice of facial reconstruction. This is the triad of procedures for covering surface defects without regard for cosmetic result which evolved so slowly through the centuries.

This has been true particularly since the popularization of "thick, split-skin grafts" by Blair and Brown and the more recent contribution by Padgett of a mechanical means of obtaining them.

I have never seen a skin flap, either pedicled or "free," transplanted from a distant area that matched and blended with its surroundings. It becomes the most prominent and noticeable feature of the face even under the best of circumstances. It is very frequently pigmented or has a glazed, grayish white cast and is necessarily framed in a scar of varying dimensions. Utilization of flaps from the forehead results in a disability which can never be corrected. The results are more functional than cosmetic except in certain rhinoplasties.

These are "procedures of necessity" rather than the "procedures of choice" which their universal use today would seem to indicate. Must we wait again another period of years before we properly evaluate and utilize other methods which produce better results? The surgeon must realize that the end results of pedicled flaps, rotated forehead flaps, and free skin grafts are such that they should never be considered procedures of choice for facial repair even though they must be employed frequently as procedures of immediate necessity. A plan of repair which employs such flaps as the only procedure available immediately should contemplate ultimate replacement of the transplanted skin with normal skin from the vicinity whenever possible.

This general trend of thought and procedure is unilateral thought in respect to the dual responsibility of the surgeon—i.e., to restore to normal, or as near to normal as possible, both function and appearance.

The thinking must become bilateral if the surgeon is to discharge his obligation to the civilian and the soldier. The objective must include restoration of both function and appearance. The latter precludes any plan of repair which adds a single unnecessary scar or foreign tissue to any visible portion of the body.

The surgeon's major thought in planning a reconstruction must thoroughly canvass the possibility of utilizing tissue from the neighborhood, transferred in one of the several ways available, before giving any

consideration to the procedures so universally employed in recent years. The employment of the principles of Z plastic, multiple excision, and interpolated flaps from the vicinity of the defect should have first consideration in the planning of a correction whenever the surgeon may choose his procedure.

I was able recently to contrast typical examples of the current conception of repair, as recorded in recent journals and observed among the patients of my contemporaries, with the results obtained by utilization of Z plastics, multiple excisions, and interpolated flaps from the neighborhood and combinations of these methods through the permission of authors, publishers, and colleagues to use their material.[13] The cases cited then and here are examples of the excellent technical accomplishments of master surgeons. The contrasts in the repaired areas result from differences in planning and choice of methods rather than from differences in surgical skill. A few contrasting results are offered to emphasize our contention.

The lobule of the nose, the major portion of the alae, and the columella may be reconstructed without the addition of any visible scars other than those on the nose itself. This is equally true, also, for partial losses of the upper half and the lateral walls.

Traumatic distortions of the eyelids due to misplacement of tissue and scar contraction are readily and perfectly corrected by properly planned Z flaps. The destruction and distortions due to burns present a different problem requiring careful consideration of the cosmetic as well as the functional results. The generally accepted practice of grafting skin from another eyelid or that taken from the mesial surface of the ear to correct an ectropion usually accomplishes the desired result, but under some circumstances the effect is grotesque. An example is pictured in Fig. 1. The operator limited his planning to one of the triad of procedures, so universally employed. He chose, in this case, to correct ectropion of the upper and lower lids and both lips with split skin taken from the abdomen. The surgery is accomplished perfectly but the appearance of the patient is ridiculous. The greenish gray color of the grafts framed in the surrounding pearly gray-pink skin of the burned face and forehead is startling. The strips about the margins of both lips produce the effect of a made-up clown! There was no art in this procedure except the mechanical one. Rotated, interpolated flaps from the borders of the defects would have corrected all of the functional disabilities with skin that matched and blended with its surroundings.

The reconstruction of a lip is most exacting. Its ultimate function and appearance determine largely the character of the face. Those procedures, too frequently adopted, which cut, shift, and destroy the muscles of expression should never be employed. It may be stated as a general principle that a part or all of a lip, either upper or lower,

can be repaired with the tissues surrounding the defect, provided that there is not extensive destruction of those areas. The partial losses are quite perfectly repaired by the Abbé procedure. The double scar resulting from this implant may later be reduced to a single one by undermining and sliding the skin of the original lip. Larger and total losses can be corrected by utilizing rotated flaps of skin and subcutaneous tissue from the borders of the defect without any damage to the muscles of expression. The lining is provided either by shifting buccal mucosa, by turning a "hinged" skin flap from the margin of the defect and

Fig. 1.—Second and third degree burn. Ectropion of eyelids and lips was corrected by release and dissection of the scar and grafting with split skin from the abdomen. Color contrasts do not appear adequately. The grafts are greenish gray and the facial scarred skin a pearly gray-pink. The appearance is that of a made-up clown.

later replacing this with buccal mucosa by multiple excision, or by grafting the covering skin flap with hairless full-thickness skin before the reconstruction. The choice of these procedures depends upon the extent of the defect.

The patient seen in Fig. 2 presents a loss of the major portion of the left half of the upper lip, decided atrophy and pigmentation of the soft tissues of the infraorbital area of the face and lateral half of the nose, and ectropion of the left lower lid. This resulted from childhood treatment of a nevus with radium and roentgen rays.

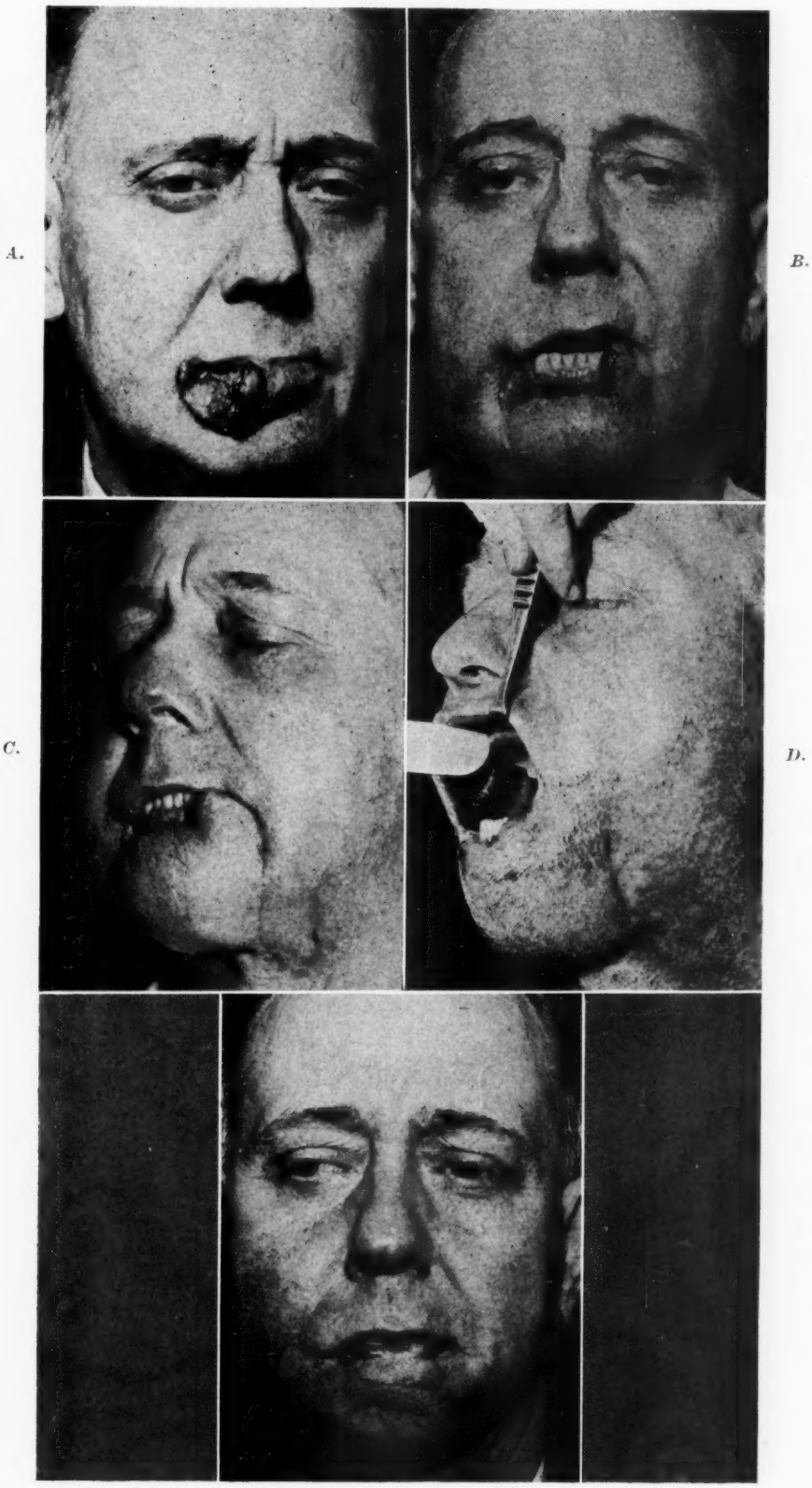
The surgeon had a "choice of procedure" in repairing each of the several defects. The lip has been restored by utilizing rotated flaps of

A. B.

C. D.

Fig. 2.—Ectropion, cataract, atrophy of the skin and underlying tissues, arrested bone development, and partial destruction of the lip as the result of roentgen irradiation of a pigmented nevus in early childhood (*A*). Reconstruction of the ectropic eyelid was done with a full-thickness graft from the upper lid. Surgical adhesions of the lids prevented contraction during the period of organization. Outline of the flaps for reconstruction of the lip and face (*B*). Construction of the lip was completed, and surgical adhesion of the lid margins and advancement of normal skin into the atrophic area (*C*). Appearance two months after completion of the repair (*D*). Compare Figs. 5 and 6. (Courtesy of Smith, Ferris: J. A. M. A. **120**: 352-8, 1942.)

Fig. 3.—Carcinoma of the lip and cheek (*A*), lip and cheek defect after surgical destruction and repair. The skin of the chin has been undercut, elevated, and sutured to the remnant of mucosa in the labial sulcus. Labial and buccal mucous membrane have been sutured to the skin bordering the defect (*B*). The covering skin flap has been outlined on the cheek and neck and "delayed" (*C*). A tube of buccal mucosa has been prepared in the cheek for transfer to furnish the vermilion border of the lip (*D*). Completed lip several months after construction (*E*). The organized and relaxed flap is ready now for cosmetic correction.



A. B. C. D. E.

Fig. 3. *(For legend see opposite page.)*

A. *B.* *C.*

Fig. 4.—Scar from a third degree burn; destruction of the nasal skin covering and the left ala; hypertrophied scar and keloid (*A*). The nose has been covered with whole thickness skin from the mesial surfaces of the ears. A Z plastic has placed normal skin in position for multiple excisions of the hypertrophied scar on the cheek (*B*). Appearance as the reconstruction nears completion; the Z plastic for removal of the scar on the lip is incomplete (*C*). (Courtesy of Smith, Ferris: J. A. M. A. **120**: 352-8, 1942.)

the skin and subcutaneous tissue from the border of the defect without any damage to the muscles of expression. The atrophied, pigmented skin of the face was replaced by normal skin as the result of multiple excisions and Z plastics. The eyelid was repaired by releasing the margin of the lid, creating adhesions between the two lids, and grafting the resulting defect with skin removed from the upper lid.

The patient pictured in Fig. 3 suffered a loss of the major portion of the lower lip and some of the adjacent right cheek from excision of a carcinoma. The remaining skin about the chin was undercut, elevated, and sutured to the remnant of mucosa in the labial sulcus. The buccal mucosa was sutured to the tag of lip on the left side and to the skin about the defect in the right cheek.

The surgeon had choice of procedure and chose to reconstruct with the tissues about the defect.

The lining was furnished by a hinged flap, carrying fat, turned from the border of the loss in the right cheek. The cheek defect thus created was closed by sliding the bordering skin. This lining was replaced later with buccal mucosa from the left cheek by multiple excision. The covering skin was furnished by a rotated flap carrying fat from the left cheek (Fig. 3*C*) and the vermilion border was supplied by a tubed flap of mucosa from the right cheek (Fig. 3 *D*). The cut ends of the muscles of expression on the right side were ultimately introduced into the reconstructed lip.[14]

The functional and cosmetic results are excellent. The muscles of expression are uninjured and the scarring is minimal.

Functional and cosmetic disabilities of the face such as those resulting from trauma, burns, and pigmentation are corrected most perfectly by multiple excisions, Z plastic, and interpolated flaps rather than by the triad of procedures usually adopted.

In Fig. 4 is presented a patient with hypertrophied scar and keloid following a third degree burn which has been corrected by Z plastic and multiple excisions. Normal bordering skin, which matches perfectly, has replaced the defect. Contrast this with the cosmetic result shown in Fig. 5.

The patient seen in Fig. 5 presented a condition similar to the one pictured in Fig. 4 except that the scar area extended lower on the side of the neck. The surgeon, in one of our large teaching centers, had a choice of procedure. He selected one of the usual triad and tubed a pedicle on the neck and upper thorax. Chest skin which does not blend—it is dead white—was planted in the face and a large additional scar created on the neck and chest. The surgery relieved a functional disability consisting of a distortion of the angle of the mouth and some limitation of motion and left everything to be desired cosmetically. There was no art in this planning and procedure. Contrast the result with that in Fig. 4.

In Fig. 6 is presented a pigmented, hairy nevus on the left side of the face and forehead of a beautiful child. A distinguished colleague followed the usual practice with excellent technical results but with much to be desired in final appearance. The nevus occupying the left temporal region was replaced by a full-thickness graft from the abdomen, which the operator states "retains a lighter shade than the remainder of the normal skin." Several excisions within the nevus on the cheek and replacement of the remainder with a split-skin graft (0.017 inch) from the back completed the repair. Pigmentation and color contrasts are not evident in the photographs.

A. *B.*

Fig. 5.—Third degree burn of the right cheek, chin, and area of the digastric triangle. Repair was done with a tubed pedicle flap raised from the neck and right chest with the creation of extensive additional scar. The color contrast with the normal facial skin is not shown adequately but the quality of the cosmetic result is obvious. Compare with Fig. 4.

The use of grafted skin on the temporal region was a "procedure of necessity" while the employment of a graft on the cheek was not. A continuation of the multiple excisions combined with a Z plastic to change the line of traction on the lower lid would suffice to replace the nevus with normal bordering skin.[12]

This result affords the opportunity of comparing the cosmetic value of full-thickness and split portions of skin on the same patient. The procedure, despite its skillful execution, replaces a decided cosmetic

A. *B.* *C.*

Fig. 6.—Pigmented hairy nevus (*A*). The lesion in the temporal region is replaced by a full-thickness skin graft. The lesion on the cheek was partially removed by multiple excision and finally replaced with a split skin graft. Color contrasts do not appear. The graft remains the most arresting feature of the face (*B* and *C*). Compare Figs. 2 and 7. (Courtesy of Dr. Warren Davis, Smith, Ferris: J. A. M. A. **120**: 352-8, 1942.)

blemish with another of less degree which remains a definite disability. Compare the cosmetic result with Figs. 2 and 7.

The patient pictured in Fig. 7 presents a similar problem in planning. A hemangioma with early malignant change involved the left lip, face, and mesial wall of the orbit. It has been removed by a combination of

Fig. 7.—Hemangioendothelioma involving the left upper lip, face, and mesial portion of the orbit (*A*). Removal and reconstruction by multiple excisions and Z plastic, appearance after the initial excision (*B*). This condition followed a Z plastic and two subsequent excisions. The circular scars result from coagulation of large dilated capillaries which rupture spontaneously (*C*). The lip and face were covered with normal skin at the end of eighteen months (*D*). Compare with Fig. 6.

multiple excisions and a Z plastic. The large dilated skin capillaries were punctured with a fine hypodermic needle and coagulated. The area is covered with normal skin and presents minimal scarring.

SUMMARY

1. Most plastic surgeons do not recognize and utilize some procedures which will improve materially the end results of surface repair.

2. The cosmetic result of such repairs merits more consideration.

3. The evolution of and the universal modern practice in facial repair has been profoundly influenced by the popularization of tubed pedicle flaps, free grafts, and rotated flaps from the forehead.

4. Reconstructions utilizing these methods are procedures of necessity rather than procedures of choice.

5. A better understanding of the varied uses of Z plasties, the employment of the principle of multiple excision, and the use of flaps of normal tissue from the vicinity of the deformity will improve greatly the end results.

6. The plastic surgeon in this war has a solemn obligation to the soldier as well as to the casualty victim in civilian life which can be discharged only by careful consideration of the art and finesse of the practice.

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TREATMENT OF BATTLE CASUALTIES AND STREET OR INDUSTRIAL WOUNDS OF THE FACE

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EARLY accurate replacement and fixation of distorted bone and damaged, cut, or torn face tissues will on the average give a quite acceptable, if not really good, restoration within a period to be measured by weeks or a few months. However, whether from battle casualties, or street or industrial accidents, these may be of such severity as to cause one not familiar with their early care or potential outcome to hesitate or putter until the time for easy adjustment has passed. Under combat conditions such delay can be unavoidable, but regardless of circumstance it will too often change a problem of simple readjustment and fixation to one of long-drawn-out hospitalization, repeated operative attempts, and a comparatively poor final result. A relatively minor consideration is that the delayed recovery piles up an unnecessary expense that must be borne by someone—the casualty, the industrialist, or the taxpayer.

The basic principles underlying the care of face wounds are essentially the same as those for wounds in extremities or parietes, but details of procedure and comparative result may vary greatly. An obstructed airway will cause death quicker than will most hemorrhages; an open joint, abdomen, or chest wall demands immediate closure, possibly with simultaneous débridement; but penetration of the mouth in itself means nothing, and on the face débridement is never indicated as a prophylaxis. Restoration of bony relation and the suturing of wounds on the face should be meticulously accurate. The teeth are a unique factor that can be used to gauge fracture adjustment of the bones in which they rest and in most cases are used for fixation, and the dentures which replace them can to a limited extent serve the same purpose.

Early treatment can be summarized under five procedures, enumerated in the order of their importance, the first two being lifesaving and the others influencing treatment time and the quality of result.

1. Establishment of a free airway, control of bleeding, and shock.
2. Make no tight closure of wounds within the floor of the mouth without ample provision for inferior drainage.
3. All displaced fragments or masses of the face bones should be restored to and fixed in proper position as early as is practical; if not immediately, preferably within the first two or three weeks.
4. Do not remove from the face any still-attached bone or possibly viable soft tissue.

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5. Other things permitting, all full thickness face and neck burns should be cleaned and grafted within three or four weeks from time of injury.

TREATMENT

1. The most demanding indication is establishment of a free airway, but, directly or indirectly, hemorrhage is likely the common cause of death in face wounds. At the field hospital or even a dressing station, the bleeding vessel can be caught or effective packing might be done, even of the pharynx after a stab tracheotomy. Where need be, the common carotid might be ligated; if the patient is under 30 years of age the latter is not apt to cause permanent brain damage. In these cases, death might result from exsanguination, aspiration, or shock; therefore, one so wounded should be placed semiprone to give a free airway during transportation and while making attempts to control bleeding. An old, somewhat heroic procedure for uncontrollable bleeding is to hold the man erect until he faints and then quiet him with a small dose of morphine. An early transfusion can again start bleeding from an unligated but clot-controlled vessel wound.

2. The prohibition against closing wounds in the floor of the mouth stands as stated, for it can initiate a spreading induration, possibly fatal under conditions of transport.

3. Next to life preservation, the most demanding indication in the care of the recently injured regards continuity of the bony framework.

Fractures in the mandible do not impact and displacement here, due to muscular pull, will vary with the position, direction, and number of fracture planes. Those within the maxillomalar mass or "upper jaw" are frequently impacted, and when displacement is present is due to the original violence or to gravity. Jaw fractures in most instances, if seen early, can be diagnosed by digital examination and intraoral inspection; where convenient, this may be checked by x-ray, but there is seldom reason to allow want of a radiograph to delay replacement and fixation beyond the time of election.

Most fractures of the body or ramus of the mandible, either single or multiple, should have immediate restoration of occlusion by the Gilmer plan of wiring the lower to the upper teeth. Those of a tooth-bearing area are usually contaminated by mouth secretion, and an early stab drainage opening made from under the border into each fracture plane will largely prevent the induration and death of partially detached bone fragments, due to pocketed mouth secretion. Displacement of an anterior segment that lacks teeth suitable for anchorage can be controlled by a wire loop passed around the segment, closely hugging the bone, and fixed either to a tooth or wire arch above, or by releasing muscle-pull with an open-bite (Gunning) splint. For body fractures of edentulous patients, the dentures make an excellent splint when

the two plates are fixed to the mandible by circumferential wiring after the incisors are removed to permit feeding, and certain others of the molar and premolar teeth to facilitate the circumferential wiring.

Displaced alveolar fragments and teeth should be pushed into position. Separation of the coronoid process or the condyle of the mandible is ordinarily best treated conservatively without regard to the local displacement by fixing the jaws in occlusion for three weeks or for a shorter time if other means are used subsequently. A blow on the chin can, without fracturing the mandible, cause collapse of the bony auditory canal or fracture of the odontoid process of the axis.

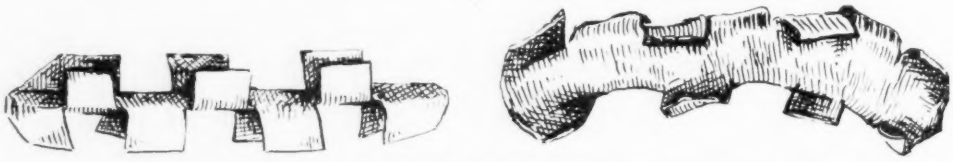

Fig. 1.—Front and side views of the splint for the molar-bicuspid region. For multiple fractures and fractures in the incisor area, the splint can be made to conform to the whole of an upper or lower denture or, as an open-bite splint, can be applied to both dentures at the same time.*

Fig. 2.—Showing the splint in position, covered by modeling compound in which the teeth are buried, with the compound pressed tightly in above the necks of the teeth.

Total separation of the maxillary mass from the base of the skull, and transverse fractures through the body are best fixed in place by wiring the upper to the lower teeth, or using the patient's dentures as already described. In many instances, however, this final fixation must be delayed until an airway is insured, until swelling subsides, or until maxillary displacements are corrected, but during the waiting period the maxilla should not be allowed to sag downward. It may be supported by a reversed Kingsley splint supported by a bandage over the vertex as used by Gilmer, or a Gunning open-bite splint.

With fractures of the maxillae above the palate, the displacement may be backward, uptilted, or lateral; in any case, early wiring of the teeth into occlusion after releasing the impaction and insuring patulence

*Illustrations depict the contrived plan of Dr. James A. Brown, Chief of the Dental Service in Base Hospital Unit No. 21 with the British in the last war, of using splints made of jam tins held in place by modeling compound, which could be easily and quickly applied with considerable accuracy and removed at any time, and which were very appropriate for emergency splinting in the forward areas.

of the nasal airway is likely all that is required, but late correction has in our hands proved quite a formidable procedure. A mass sagging of the face after fracture through the orbits is also treated by the same dental fixation even though both jaws be broken, but for an interval the maxilla might advantageously be supported by the Gilmer plan of reversing the Kingsley splint, with the bandage encircling the vertex. This latter is especially applicable for patients with nasal obstruction or those seen late but with no fixation. However, this inaccurate up-pull should be discarded and the two arches wired in occlusion before bony fixation takes place; otherwise a permanently uptilted dental arch is likely to result. The cooperating dental surgeon will be familiar with the types of splints mentioned and with dental wiring.

In appropriate cases, wiring the upper to the lower jaw is being discarded in favor of direct fixation of the fractured bones by external splints attached to the fragments by screws piercing the soft tissues or by metal spikes or wires driven lengthwise through the bone. The latter appears to be simpler and worn with much more comfort.[3]

Displacements of the zygomatic bone, commonly called fracture of the antrum, are usually downward, backward, and outward, with outward bowing of the zygomatic process, and firmly impacted. There are various plans of breaking this impaction; the one commonly advised is insertion of pries or hooks through external incisions, using the frontal bone as a fulcrum. However, the displacement frequently includes an unrecognized bursting fracture of the orbit with downward displacement of the floor; if this latter is not included in the replacement it will later still be revealed by the sunken and depressed globe that will become evident as the orbital swelling and hemorrhage subside. Both for this reason and also the ease with which the cheek bone can be replaced, we open the antrum through the canine fossa, the impaction is broken up with a pry, the floor of the orbit is examined and, if need be, pushed up into place by the examining finger within the antrum; the body of the bone and the floor are fixed in place by a folded strip of mildly antiseptic gauze packed into the cavity in an orderly manner, the end protruding through a small opening in the unsutured anterior part of the mucous incision. When this gauze strip is removed three weeks later, the flared-out trap door of antral wall is pushed into place.

For displacements of the orbital borders, the nose, or the bony part of the external auditory canal, impactions should be broken up and proper relations established; within the nose, mucous tears should be closed with a few tacking sutures, and displaced cartilage held in place by a splint or gauze packing.

Impacted nasal fractures can usually be freed within the first three weeks by the prying elevator which will permit the broken or bent septum to resume natural position, but the replaced bones might need

fixation. One or possibly two of the three following plans will accomplish the latter. (1) For a depressed dorsum with lateral spreading of the nasal bones, the bridge is pried free and a heavy curved "surgical" needle carrying a wire or strong silk suture transfixes the base of the nose through the fracture lines, above and below, the needle entering and emerging from the skin slightly lateral of the fracture lines in such a way as to draw in some of the laterally displaced proper nasal covering. The bones are held in normal relation by tightening the mattress suture over a narrow lead plate at each side of the nose. (2) For lateral mass displacement, use the wire-carrying needle inserted so as to engage either the anterior nasal spine, the lower corner of the opposite nasal bone, or the dorsal border of the cartilage, to form a subcutaneous loop, both ends of which traverse the vestibule and the cheek tissue, to emerge above and anterior to an anchoring upper molar tooth to which the guy wire is attached after drawing the nose into a somewhat overcorrected position. (3) After certain complicated or comminuted fracture reductions, the bridge of the nose can best be held in position by an intranasal armature that below is attached by a universal joint to a vulcanite base plate cemented to the incisor teeth; any persistent uptilting of the tip can, if necessary, be drawn by a second guy wire that transfixes the septum near the dorsum. This splint is particularly useful where the freed nasal bones have been driven in deeply between the maxillary processes or where there is much comminution of bones and septum. Deep backward displacement of the bridge might easily be complicated by an unrecognized fracture of the cribriform plate of the ethmoid, and a week or ten days might be profitably expended on prophylactic measures directed toward protecting the cranial contents. This same delay applies also to the replacement of a pushed-in fragment of the outer wall of a frontal sinus and to displacements of the upper orbital border, but those of the outer border of the orbit can be replaced immediately.

Regarding the release of impacted fractures of the face, especially those of the zygomatic bone, and deep backward displaced nasal bones, or those involving dentigerous bone, complicated by fever, it is a perfectly safe practice to delay breaking up the impactions for a week or ten days until some local immunity to infection is established naturally or by medication. In two cases of early forceful replacement of the zygomatic bones, I have seen a limited bone necrosis follow the manipulation, and in several cases of fracture of the maxilla there has been considerable elevation of temperature that might have been related to some previously quiescent apical abscess. A posteriorly displaced nasal bone impinging on the cribriform plate of the ethmoid might have caused a dural tear, which might be really unfortunate with an ethmoid or chronic nasal suppuration.

4. Wherever tissue condition permits, the lips, nostrils, nasal alae, columella, ears, eyelids, trap door flaps of skin, and displacements of the nasal cartilages or mucosa should be immediately tacked in place as should also mass displacements of face tissues. A soldier with wide cheek tears or loss might be rendered transportable earlier and with greater comfort by following the British practice of tacking the mucosa to the skin across the raw surface.

The classic "débridement" has no place in face injuries, but after the removal of shreds fresh clean wounds may, possibly as a first-aid procedure, be drawn together, preferably with catgut that engages the subcutaneous tissues and will not risk added suture scars that might permanently mar an otherwise very good secondary correction. Scraped areas of skin, such as occur in street injuries, should be immediately scrubbed with the brush until all dirt and foreign matter are removed. The implantation of burnt grains of black powder should be individually removed with a pointed bistoury and each little wound sutured before the powder grain has time to disseminate.

5. Burns that cause full thickness skin loss can by proper care, local and general, usually be made ready for split skin grafting within three to eight weeks after the injury. When the graft is applied to such movable areas as lip, cheek, or eyelid, the graft with its dressing is best fixed by suturing the latter in place. This type of graft, where unopposed, will shrink possibly 60 per cent, but early coverage will save an immense amount of suffering and expense, and will allow later replacements or additions to be done at times of election.

With the greater naval activity now occurring, the increasing predominence of air fighting, and the eventual rapid movement of ground troops, it seems likely that the proportion of war injuries of the face will greatly decrease. However, to the individual casualty, the proper care of his damaged face will remain just as important as it was when this type of surgery was well in the spotlight.

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EARLY TREATMENT OF GUNSHOT WOUNDS OF THE FACE AND JAWS

Case Histories of Patients Treated During World War I

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SINCE the outbreak of World War II, the treatment of gunshot wounds of the face and jaws has been extensively discussed. It is, therefore, quite natural for me to refer to my own clinical records and papers written during the last war, and to judge them after twenty-five years of added experience in maxillofacial and plastic surgery. It is gratifying to note that the basic methods of treatment recommended then have not changed. It is important to record that much progress has been made in the use of the sulfanilamide drugs, in the treatment of shock, in the administration of intravenous fluids, and in the bacteriology of wounds. Many new appliances have been suggested and designed for the immobilization of fractures of the facial bones. Medical, surgical, and mechanical progress have not modified the principles of treating jaw cases. For these reasons I am taking the liberty of using parts of my former articles to express my present views.

The treatment of facial injuries may be divided into two distinct periods. The first, or early period, which covers the three to four weeks following the receipt of the wound, is the most critical for the patient. This is the period of initial exhaustion, of loss of blood, of pronounced sepsis, and of great pain and mental depression. This is also the time at which alarming complications, such as bronchopneumonia, secondary hemorrhage, and general infections are most likely to occur.

After this critical first period, the patient enters the second period. At this time, depending upon the severity of the case, the treatment of the patient is confined chiefly to further repair of the bony tissue by means of splints, to the construction of prosthetic appliances, to minor operations, and to plastic operations for the reduction of the facial deformity. Following this is the convalescent period.

In this discussion emphasis will be placed on treatment and complications of gunshot wounds during these early stages. First it is well to note the differences between war and civilian injuries, or to use two convenient terms, gunshot and accidental wounds.

Accidental cases are nearly always caused by a fall, a blow, a kick, or an automobile collision; something hitting the victim, or the victim hitting something violently. The patient's life may or may not be in danger. He usually reaches a hospital within four to six hours after injury; facial injuries are susceptible to primary suturing, the lines

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of fractures are well defined, there is no loss of bone except teeth and alveolar process, infection is not serious, and complications are not frequent.

By contrast, in gunshot wounds the missile may carry away anything from a few spicules of bone to a considerable part of the face. The foreign body has caused the shattered bone to tear the soft tissues with almost explosive violence. Multiple fractures radiate in many directions. The lacerations of the muscles and the destruction of bone obviously indicate free movement of the remaining parts. In this case the face is horribly mutilated but the gaping aspect of the wounds facilitates an appraisal of the damage with considerable accuracy.

A large number of facial wounds with a small entrance and a small exit are seen. The severity of such wounds depends almost entirely upon the anatomic location and the path of the piece of metal. Through-and-through wounds of the anterior part of the face may cause extensive destruction of the teeth and comminution of the bone, but in the main do not lead to alarming complications, providing adequate treatment at an early period is effected. Contrary to this, however, wounds involving the posterior part of the face, especially those of the pharyngeal, carotid, and lower molar regions, are particularly dangerous. Such injuries may cause bilateral fracture of the mandible, and in many cases be situated near enough to important blood vessels to give a probable chance of severe hemorrhage.

The tongue and the floor of the mouth are liable to serious injury along with either the upper or lower jaw. If the injury is limited to the apex or dorsum of the tongue its profuse blood supply promotes healing in spite of severe laceration or even sloughing. The tongue may be greatly swollen and often dark purple in color, and, in spite of the open position of the mouth, it may protrude beyond the lips and at times seriously effect the breathing.

Wounds of the Lower Part of the Face.—Wounds of the lower lip are common in injuries where there is an obscure entrance posterior and inferior to the mandible on the neck or face. The missile has traveled forward, causing extensive laceration and fracture. This type is sometimes very extensive, involving loss of the chin, the sublingual region, and a large part of the mandible. These cases are relatively easier to treat than those of the posterior face and throat because the wounds are accessible, are less prone to complications, and the lacerated tissues may be repaired at an early date.

Wounds of the Upper Part of the Face.—Injury to the upper part of the face is less common, but it may be more dangerous and ultimately lead to greater deformity, particularly if the injury extends to the nose, the eyes, the ears, or the zygomatic region. The maxilla is prone to great comminution and considerable loss of bone, and in some rare instances practically the entire maxilla and the septum of the nose have

been carried away. The involvement of one or both antra is common, and might almost be said to be a certainty. Fractures of the cribriform plate in injuries of this type are the cause of most fatalities.

Most soldiers, when questioned on their arrival at the hospital, state that while they bled quite profusely, they were able to reach the dressing station either unaided, or with the help of a stretcher bearer. However, loss of blood combined with fatigue and exhaustion naturally tends to lower the resistance and make the patient more susceptible to further complications. Having all this in mind, it is necessary that the preliminary treatment should consist of making the patient comfortable, taking measures to control infection, and increasing the resistance of the patient in preparation for further treatment.

The foregoing statements represent a fairly accurate description of face and jaw injuries as seen and described twenty-five years ago, and there is no reason to think that they will be different at the present time.

I shall not discuss various local measures such as feeding, nursing care, dressing of wounds, or the general measures such as administration of fluids, antitetanus serum, and chemotherapy, but will limit this discussion to a few of the important aspects of treatment.

A careful study of a large number of treated cases has revealed some interesting facts that are well worth recording.

1. The general care of maxillofacial cases is more effectively carried out when such patients are segregated in a certain designated center, or when that is not possible, a section of the general hospital reserved for the care of patients with maxillofacial injuries. The difficult problems of feeding, nursing, and frequent dressings can only be effectively carried out by specially trained medical officers, nurses, and attendants. It has been found that patients with jaw injuries are happier when they have their own quarters and recreation facilities apart from the other patients in a general hospital.

2. All gunshot wounds are infected from the beginning, no matter how soon the patients are admitted to the hospital; consequently, they must be treated as such. After making the patient comfortable with supportive treatment, our procedure has been to apply frequent warm fomentations over the wound, irrigations to the mouth, and at the proper time (perhaps within the first week) clean the wound surgically, preferably under local anesthesia. This consists of the removal of nonvital tags of lacerated tissue, broken-down teeth, and loose fragments scattered throughout the wound.

3. There has been a natural temptation to suture external facial wounds as soon as the patient arrives at the hospital, with the wrong assumption that this will prevent subsequent deformity. This hasty measure has caused a good deal of harm. Suturing wounds when the wound is already infected and greatly swollen does not minimize the deformity, but it tends to block drainage and complicates the procedure for the immobilization of the bone fragments.

It is possible, however, once the infection is under control, to resort to partial suturing of the radiating borders of the wound, and suturing of vital but misplaced sections of tissue into their proper positions. This suturing should not, under any circumstances, interfere with sufficient drainage of the wound or with the dental surgeon's free access to the mouth for the performance of various manipulative procedures for the immobilization of fractures. For example, if there is a large gaping wound of the lower lip, extending toward the neck, suturing of the lip should be postponed until proper dental splints have been inserted for the immobilization of the mandibular fragments.

4. Great stress has been placed on early immobilization of mandibular fractures as soon as the condition of the patient permitted it, because it was found that such a procedure made the patient more comfortable, the feeding problem less difficult, and the healing process of the wound was hastened. The general picture of the laceration was simplified and earlier repair of the lips was made possible. Immobilization should be carried out within the first week or two after the injury, unless some local or general complication makes it impossible to do so, because at this stage the bone fragments are easily manipulated and brought into alignment. The problem of adjustment of dental splints is also less difficult at this stage.

5. The complications at this stage of the treatment are local abscesses, general sepsis, bronchopneumonia, erysipelas, and secondary hemorrhage. Many of these complications are likely to appear in any wound, and are not altogether typical of gunshot wounds of the face and jaws. Secondary hemorrhage in gunshot wounds is the cause of most of the fatalities, and therefore it is worth while to discuss this subject in more detail.

In World War I, at the British Base Hospital No. 20 in France, there were 34 cases of mild and serious hemorrhage occurring from among 400 patients.[1] Sixteen cases (8.5 per cent) required operative measures for the control of hemorrhage, under general anesthesia, while the remaining seventeen cases were successfully treated by packing, clamping, or ligation of the bleeding point under local anesthesia. The majority of these hemorrhages occurred between the fourth and twelfth day following the injury; three cases took place between the thirteenth and nineteenth days; and one hemorrhage occurred on the forty-fifth day following injury. In this last case the maxilla, mandible, and skull were all fractured.

Secondary hemorrhage occurs more frequently at night, according to our records. It is not always easy to determine the source of hemorrhage, but one is principally guided by the location of the entry and exit wound in relation to the anatomic location of the blood vessels. Injuries of the upper half of the face are often accompanied by nasal

bleeding, which probably originates from the branches of the internal maxillary artery. Among ninety-one cases of fractures of the maxilla there were only four cases of hemorrhage recorded. Open wounds with extensive lacerations of the soft tissues do not usually present a serious problem, because the free drainage favors early healing of the wound, and being exposed, the bleeding point can be easily detected and brought under control by ligation or packing. In injuries involving the lower half of the face we must consider probable bleeding points from the (1) facial arteries, (2) the mandibular arteries, and (3) the lingual arteries or their branches. The location of the wound and the path of the foreign body will usually give the surgeon a fairly good idea of the source of bleeding. The facial artery, being more or less superficial, is easily brought under control by direct ligation of the bleeding point. Hemorrhage from the mandibular artery has not been frequent and is seldom serious. It usually occurs when the comminution of the mandible is at the region of the angle of the jaw. Bleeding which occurs as a result of an extensive wound at the molar region of the lower jaw, with accompanying injury to the floor of the mouth and tongue, is often from the lingual arteries or their branches. Such cases have been the most common and are the most serious. From a total of thirty-four cases, seventeen were from this source and twelve required operative measures to control the hemorrhage. Such cases have certain recognizable characteristics, the entry and exit wound usually being small, the mandible fractured bilaterally, the floor of the mouth lacerated, and the tongue usually perforated and greatly swollen.

Treatment of Secondary Hemorrhage.—The most important preventive measures are those taken toward the control of infection which have been described in the foregoing pages. It must be remembered that in spite of the patient's general condition, the jaw requires some means of support in the form of a temporary splint, as it has been observed that the cases which are most prone to bleeding are those that are accompanied by fractures with extensive displacement and mobility.

The attending nurses are instructed to report even the slightest seepage of blood from the face and jaw wounds. Although it may appear quite harmless at first, it is noted that most hemorrhages start with slight oozing of blood, perhaps continuing for hours, until it eventually becomes a profuse hemorrhage. Much valuable time will be lost if this precautionary measure is not followed.

A ward for "jaw cases" must be equipped with a special emergency tray consisting of ribbon gauze, swabs, artery clamps, forceps, dental mouth mirror, head mirror, adrenalin chloride, hydrogen peroxide, and a novocain outfit. Surgical needles and sutures must also be handy for instant use. As soon as the hemorrhage occurs the attending surgeon should send for the medical officer in charge who appears at the ward as soon as possible.

The immediate stoppage of the hemorrhage is accomplished by syringing the mouth with hydrogen peroxide, cleaning the blood clots, and packing the wound with gauze saturated with hydrogen peroxide. In order to hold the packing in the floor of the mouth a specially devised surgical artery clamp has been of considerable help. It has been our experience that hemorrhage from the lingual arteries, as well as repeated hemorrhage from undetermined origin, cannot be properly arrested by packing, therefore, as soon as the patient recovers from the shock, operative treatment should be resorted to.

Since World War I much knowledge has been acquired in the treatment of shock and control of hemorrhage and physiotherapy, as well as methods of administration of anesthetics. Military surgeons at present have greater facilities to combat complications mentioned in this communication.

In the foregoing pages an attempt was made to call attention to some important points in successful early treatment soon after injury. It is often necessary, once the convalescent stage is reached, to repair further the work on the soft tissue of the face, nose, eyelids, and lip, for improvement of the facial outline. Such a procedure may often require careful planning. Therefore, there is no necessity for hasty action. The wounded could be transferred to hospitals where ample facilities are available for such treatment.

Plastic procedures are successfully carried out when the tissues have become more healthy. As a primary measure, physiotherapy in the form of heat, massage, diathermy, etc., becomes indispensable while the patient is convalescing. When the patient, in addition to loss of soft tissue, has also suffered partial destruction of teeth and alveolar processes and palate, it is absolutely necessary to replace these missing parts with prosthetic restorations before any measure of repair of the lips and cheeks is undertaken. Such supporting appliances are indispensable as they form a framework for the repaired soft tissues and allow them to heal without contracture.

It is often also necessary to resort to transplantation of bone as a certain number of mandibular fractures will suffer nonunion, either due to hemorrhage or loss of bone, or following infection. Transplantation of bone should not be attempted until all the evidences of infection have disappeared, soft tissues of the area are free from dense scars, and finally, all necessary preparations for splinting of the jaw have been provided.

CONCLUSIONS

Treatment of gunshot wounds of the face and jaws is divided into two distinct periods: first, the early period which is the most critical stage of the patient's life, and covering somewhat between three and four weeks following injury. The second period is confined chiefly to further

repair of the deformity. This article is concerned with treatment of the first period only; second, the treatment of maxillofacial patients is more extensively carried out when such patients are segregated in an especially designated center where facilities are adequate; third, all gunshot wounds are considered infected wounds and treated as such; fourth, primary suturing of face wounds immediately after injury is found to be contraindicated in gunshot wounds of the face but late primary suturing within two weeks or so has been found practicable; fifth, immobilization of fragments should receive especial attention before late primary suturing is done; sixth, complications in early period of treatment are discussed and special emphasis given to secondary hemorrhage as a cause of most fatalities.

Fig. 1. Fig. 2.

Fig. 1 (Case 1).—Photograph showing a large wound on the right side of the face and laceration of the corner of the mouth. Portion of the right upper lip was destroyed. There was comminuted fracture of the right side of the maxilla; antrum exposed.

Fig. 2.—The photograph of the patient (Case 1) before he was operated on for final repair of the upper lip.

The case histories are selected to give an idea of the procedure that was followed in the treatment of such cases of twenty-five years ago. No attempt was made to resort to lengthy discussion of the various operations, first because the main purpose of presenting these case histories

Fig. 3.—Appearance of the patient (Case 1) following the repair of the upper lip.

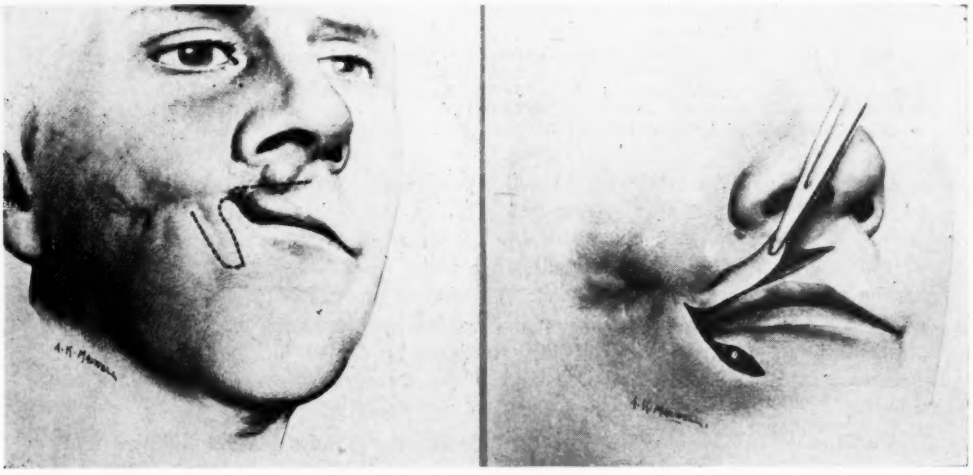


Fig. 4.—Diagram showing method of repair of the upper lip in Case 1.

is to call attention to the various steps that had been taken as well as the interval between each step in the course of treatment. We will find that some case histories are not complete. This is due to the fact that patients are often evacuated earlier because of military necessity.

Fig. 5. Fig. 7.

Fig. 5 (Case 2).—A large wound extending from the lower lip to the neck. The chin is practically missing. There was a compound comminuted fracture of the lower jaw extending from the right first molar to the left second bicuspid tooth, only one serviceable tooth on each posterior fragment.

Fig. 7.—Final picture of patient in Case 2.

CASE 1 (H).—This patient (H) was wounded on April 24, 1917, and admitted to No. 20 General Hospital April 30, 1917, six days after injury. Examination showed a large wound on the right side of the face, and laceration of the corner of the mouth extending along the cheek for about three inches (Fig. 1). A portion of the right upper lip was destroyed. The wound penetrated to the mouth, but no entry wound was visible. There was a comminuted fracture of the upper right jaw, including the palate and alveolar surfaces up to the left cuspid. The right first and third molars were loose, and all the other teeth on the right side were missing. The right antrum was exposed and was draining.

On May 8, 1917, eight days after admission, a vulcanite plate splint was made for the upper jaw. May 13, 1917, thirteen days after admission, the patient was operated upon and the wound sutured. The problem was to supply one-third of the missing part of the upper lip. The mucous membrane was stretched and connected with part of the lower lip, and a flap was taken from the side of the nose and turned

down. On July 17, 1917, seventy-eight days after admission, he was operated upon and the scars of the face were excised (Fig. 2).

Aug. 2, 1917, another operation was performed to correct the shortness of the right upper lip and the displacement of the corner of the mouth. The red borders of the upper right side of lower and upper lips were separated about an inch. A flap was taken from the side of the right lower lip and used to fill the triangular raw space (Figs. 3 and 4).

On Aug. 17, 1917, further correction of the right corner of the mouth was carried out. Aug. 27, 1917, the patient was evacuated to England.

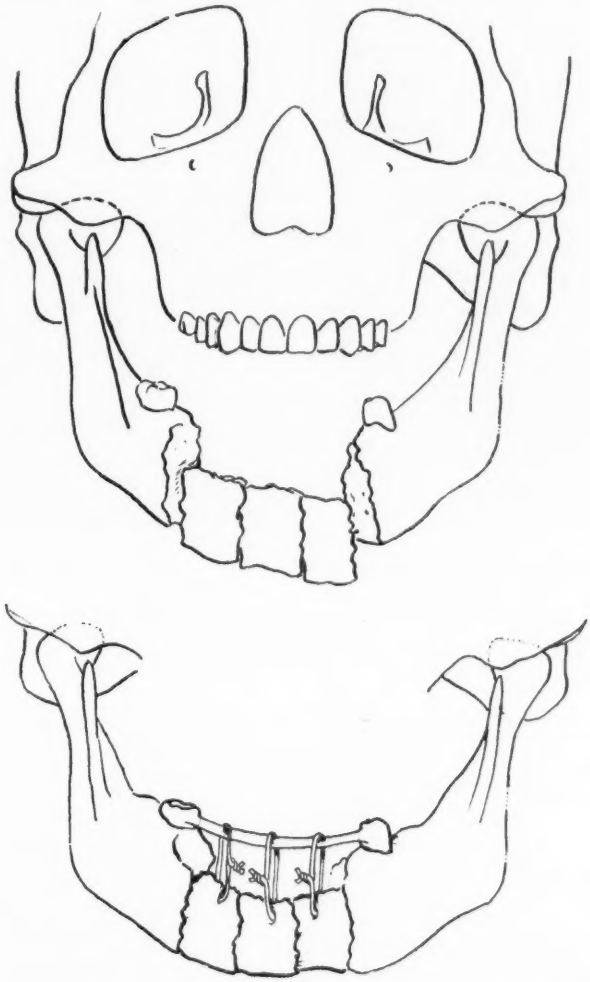
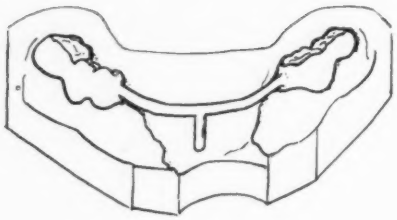


Fig. 6.—A splint constructed of bands for the existing teeth, connected by heavy arch wire, is cemented in place to immobilize the posterior segments. This arch follows the mandibular curve at about the normal lingual gingival margin of the lower teeth. Wire sutures are then passed through the exposed ends of the displaced anterior fragments and they are lifted toward the arch into a more normal alignment.

CASE 2 (C).—This patient, aged 31 years, was wounded June 27, 1917, and admitted to No. 20 General Hospital on June 30, 1917, three days after injury. There was a large wound of the face extending from the lower lip to the neck, separating the sublingual region, and the chin was practically destroyed. There was a compound fracture of the mandible from the left second bicuspid to the right molar

Fig. 8.

Fig. 10.



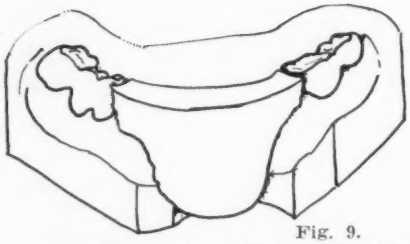


Fig. 9.

Figs. 8-10. *(For legends see opposite page.)*

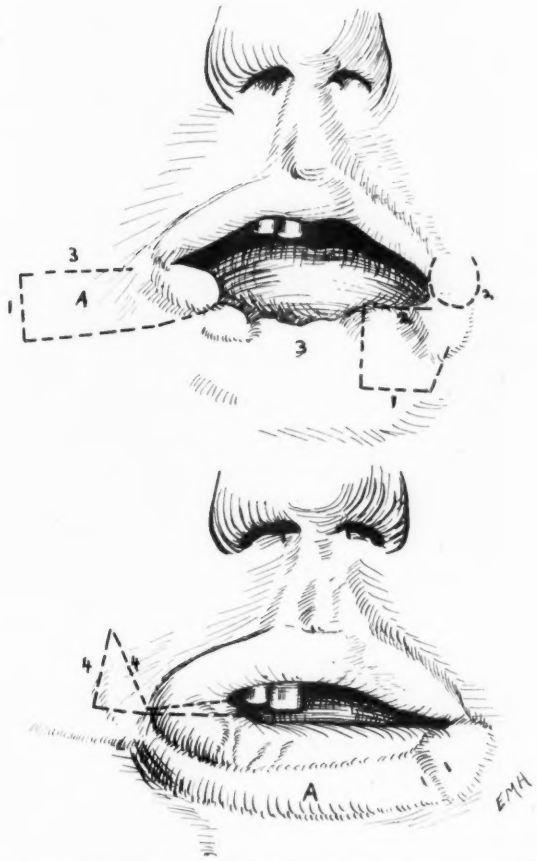


Fig. 11.—*a* shows a method of outlining flaps which together work well in creating a good functional and cosmetic lower lip. Flap *A* is rotated 180 degrees and the opposite flap is rotated 90 degrees. Each carries muscle tissue and is sustained by a good-sized blood vessel. Both together supply enough white skin and mucous membrane for the new lip. The tongue-shaped incision 2 in the first figure lies practically entirely in the mucous membrane and provides an edge for attachment for the flap, and itself contributes mucous membrane.

b shows the rotated flaps joined together, the lip completed and an advancement of the buccal mucous membrane of the lower lip to create part of the new cutaneous line. In this diagram the scheme 4, 4 shows a bulge which must be eliminated to get the final result. This is done about four weeks after the first operation.

Fig. 8.—Photograph showing loss of greater part of the lower lip. This patient also had a comminuted fracture of the anterior part of the mandible. The fracture was immobilized seven days after admission to hospital, by a band-and-wire splint with vulcanite support similar to one shown in Fig. 9.

Fig. 9.—Diagram showing a band-and-wire splint with a perpendicular T wire. A vulcanite piece with grooves is made to fit to the curve of the arch wire. This movable part has sufficient bulk to act as a framework to support the lip when teeth and alveolar processes are lost.

Fig. 10.—Photograph showing condition of patient before the repair of the lower lip (Case 3).

Fig. 12.—Condition of patient five months after injury (Case 3).

Fig. 13.—Patient suffering extensive lacerated wound with comminution of mandible (Case 4).

region, and the symphysis was destroyed. There was bony separation of about one inch, and there were only two serviceable teeth, the right lower molar and the left bicuspid (Fig. 5).

On July 8, 1917, under local anesthesia, all the broken-down teeth and loose particles of alveolar bone were removed and the main posterior fragments were immobilized by a band-and-wire splint. The displaced anterior fragments of bone were raised by means of suspended wires (see Fig. 6).

July 15, 1917, the patient was operated upon and the radiating borders of the wounds under the lower lip were sutured. On July 24, 1917, a chin piece was applied for further support of the soft tissues.

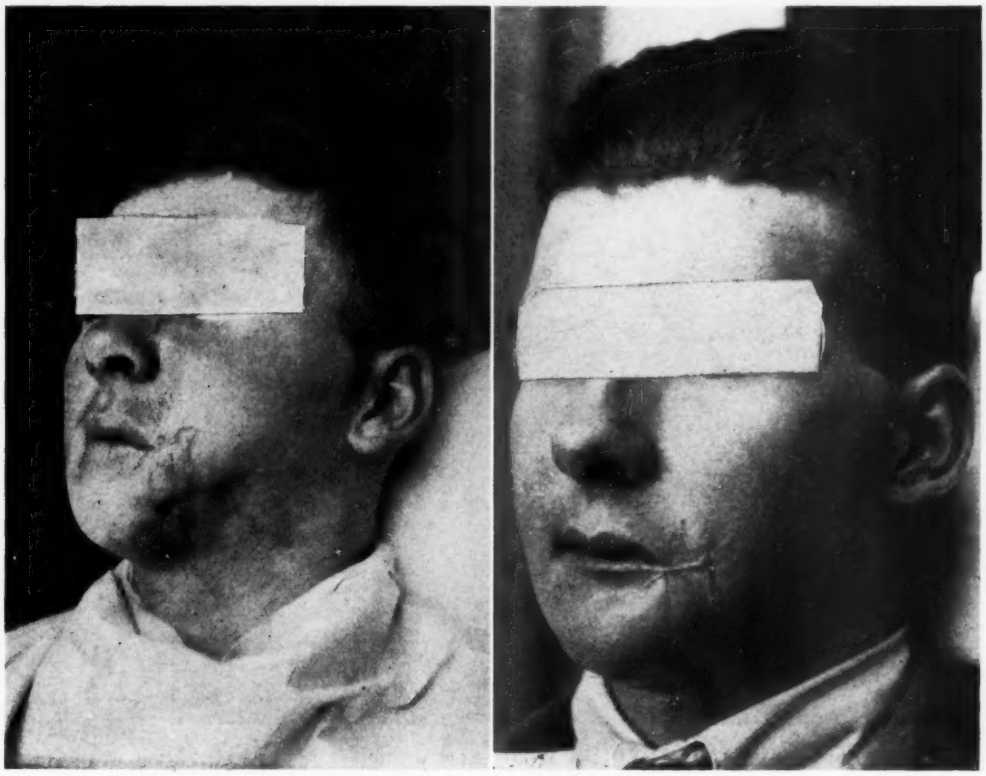


Fig. 14. Fig. 15.

Fig. 14.—The same patient four months after injury (Case 4).
Fig. 15.—Photograph taken seven months after injury (Case 4).

July 30, 1917, the necrotic bone was removed, and a molar root on the right and two lower teeth on the left extracted. The root of the second molar was exposed to be used later as an abutment for a splint.

On Oct. 9, 1917, the patient was operated upon and the scars of the chin and neck were repaired. An impression was taken for a new dental plate, and this was placed in the mouth Oct. 14, 1917.

Remarks.—The wound of the face healed with slight retrusion of the chin, due to loss of the symphysis (Fig. 7).

CASE 3 (P).—This patient was wounded May 5, 1917, and was admitted to No. 20 General Hospital May 7, 1917, two days after injury. There was a shrapnel wound

of the lower lip and left cheek, with destruction of the greater part of the lower lip and laceration of the left corner of the mouth about one inch along the cheek. There was an extensive comminuted fracture of the mandible from the first molar on one side to the first molar on the opposite side, with the anterior segment displaced downward (Fig. 8).

On May 12, 1917, the wound was debrided by the removal of loose alveolar bone and the loose right first bicuspid and cuspid teeth.

Fig. 16 (Case 5).—An extensive wound of the chin and neck, laceration of the lower lip and chin extending along the neck to the right angle of the jaw. The patient had a severe compound fracture of the lower jaw, with considerable loss of tissue from the first molar to the first molar on the other side.

On May 12, 1917, the wound was debrided by the removal of loose alveolar bone and the loose right first bicuspid and cuspid teeth. May 14, 1917, the right bicuspids, left bicuspids, and first molar roots were also extracted. There were now no teeth left between the second molars. A band-and-wire splint, with vulcanite support, was cemented over the existing teeth (Fig. 9). On May 18, 1917, eleven days after admission, the patient was operated upon and the radiating borders of the wounds were sutured. A flap of mucous membrane from the left cheek was sutured to the raw surface of the lip to form a red border for future plastic operations (Fig. 10).

June 9, 1917, the patient was operated upon and the first stage of reconstruction of the lower lip was carried out (Fig. 11*a*). On June 29, 1917, the patient was operated upon and the upper corner of the lip was raised by cutting off a triangular section, and the mucous membrane was trimmed to a better contour. Part of the mucous membrane and underlying fatty tissue was removed to eliminate the thickness of the lip (Fig. 11*b*).

Sept. 18, 1917, another operation was performed in order to correct a peculiar fullness under the lower lip. The left corner of the mouth was raised slightly to improve the outline. On Oct. 3, 1917, the patient was classified for evacuation to England (Fig. 12).

CASE 4 (M).—This patient was wounded on April 13, 1917, and admitted to No. 20 General Hospital on April 19, 1917, six days after injury. He suffered an extensive gunshot wound of the left side of the face with lacerations of the corner of the mouth extending toward the angle of the jaw and to the neck below the border of the mandible. There was considerable loss of bony tissue from the median line to the angle of the jaw (Fig. 13).

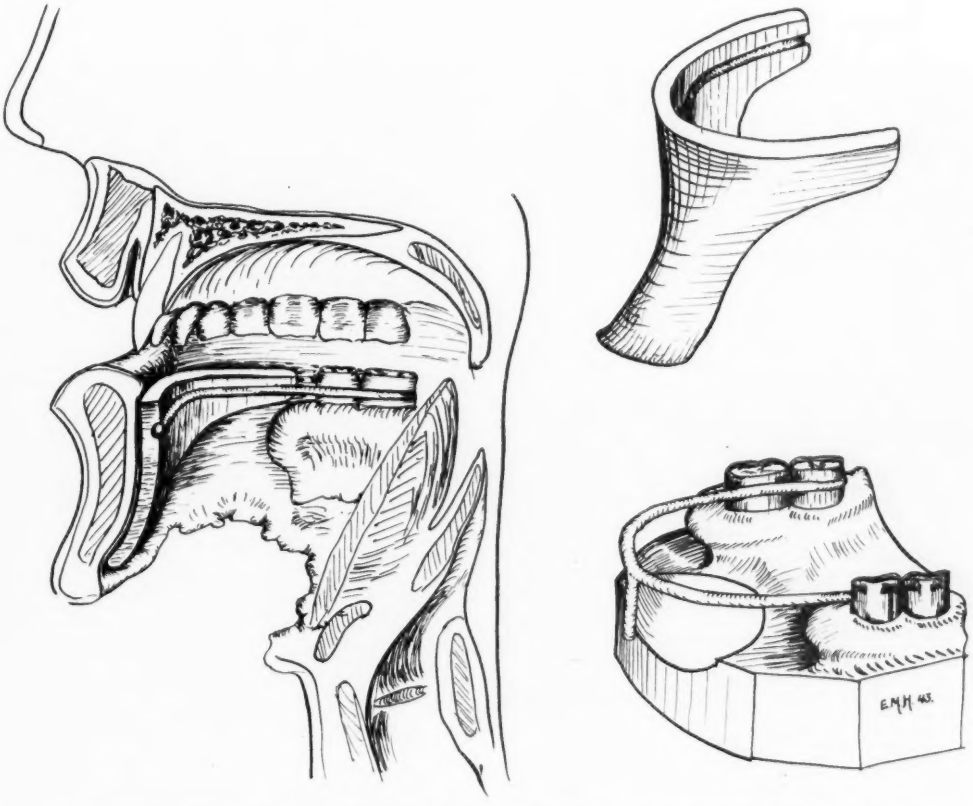


Fig. 17.—This type of band-and-wire splint was used in this case to maintain the existing posterior fragments of the mandible in their normal position, while the vulcanite support, being concave at its lower end, acts as a seat to support the lower lip and chin and prevents undue contracture. In the absence of bony framework, such supports are absolutely essential for the prevention of gross deformities (Case 5).

On April 29, 1917, a swaged cap splint with a T-shaped wire extension was cemented over the existing teeth. A large displaced fragment of bone was connected with the exposed end of the ramus with brass wires.

June 17, 1917, an operation was performed consisting of partial suturing of the soft tissues of the face. On July 1, 1917, an external appliance (chin piece) was constructed for the support of the cheek at the left angle of the mouth. Aug. 14, 1917, the patient was operated on, and the corner of the mouth which was drooping downward was raised (Fig. 14).

A new x-ray was taken, Sept. 18, 1917, which seemed to show new bone formation. In view of this, an upper splint was made and cemented over the teeth, and the lower jaw immobilized to the upper. Nov. 7, 1917, the ramus on the left side was pulled upward to avoid the danger of a false union. To do this (1) the lower end of the ramus was exposed by reflecting the mucous membrane back and holding it in position by mattress sutures; (2) a hole was drilled through the end of the ramus, and a stout wire passed through the drilled hole, connected with the bar of the lower splint, and tied with silk. Nov. 26, 1917, the wires were removed and the interdental splint adjusted in view of causing greater pressure on the left ramus. On Dec. 1, 1917, a new vulcanite splint was made in an attempt to hold the left ramus in proper position. Dec. 3, 1917, the patient was operated on for repair of the scars of the left side of the face (Fig. 15). Feb. 26, 1918, the patient was evacuated to England.

Fig. 18.

Fig. 19.

Fig. 18.—Photograph showing lip sutured and supported by a splint shown in Fig. 17 (Case 5).

Fig. 19.—Patient at the time of evacuation to England (Case 5).

Note.—This record shows clearly the difficulties I experienced in holding the posterior fragment in position with intraoral appliances. An extraoral appliance of the Roger Anderson type would be the answer for such cases.

CASE 5 (J).—This patient was wounded on Nov. 6, 1917, and admitted to No. 26 General Hospital on Nov. 10, 1917, four days after injury. Examination showed an extensive wound of the chin and neck, and laceration of the lower lip and chin

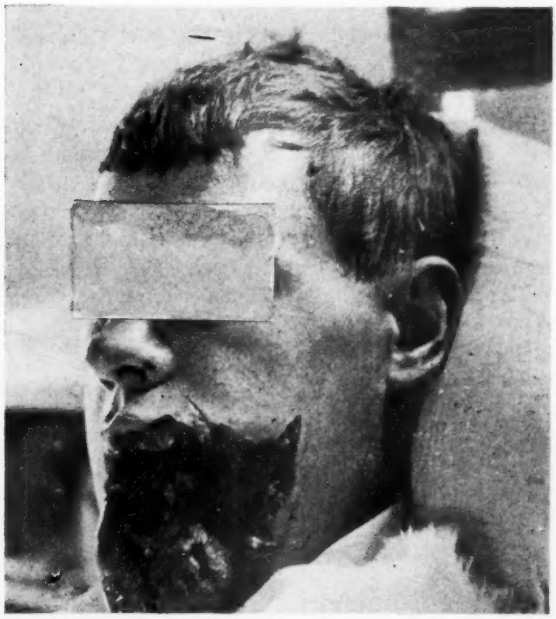


Fig. 20.—Photograph showing extensive laceration of the left side of the face, corner of the mouth, tongue, and lower lip. There was extensive comminution of the lower jaw involving the anterior section of the mandible. Several isolated fragments of bone were markedly displaced downward and backward (see X-ray, Fig. 21). In the upper jaw there was a fracture extending from the left cuspid to second molar region (Case 6).

Fig. 21.—X-ray of Case 6. The comminution of the lower jaw extended from the angle on the right to the left second bicuspid region, which was edentulous on that side. Anterior fragments of bone grossly displaced downward and backward toward the base of the tongue.

extending along the neck to the right angle of the jaw. The patient had a severe compound fracture of the lower jaw, with considerable loss of tissue from the first molar to the first molar on the other side (Fig. 16).

On Nov. 16, 1917, six days after admission, the patient was operated upon under novocain anesthesia, for the removal of the left first bicuspid, cuspid and lateral teeth, and the loose bone which carried the left lateral and cuspid. Nov. 20, 1917, ten days after admission, splints were placed. The only remaining lower teeth were the right third molar and two left molars. The band-and-wire splint was fastened in place with vulcanite support (Fig. 17).

On Nov. 22, 1917, twelve days after admission, the patient was operated upon and sublingual adhesions were severed to release the lip and chin. The lower lip was sutured and held in position with a splint (Fig. 18).

On Jan. 9, 1918, the patient was classified for evacuation to England (Fig. 19).

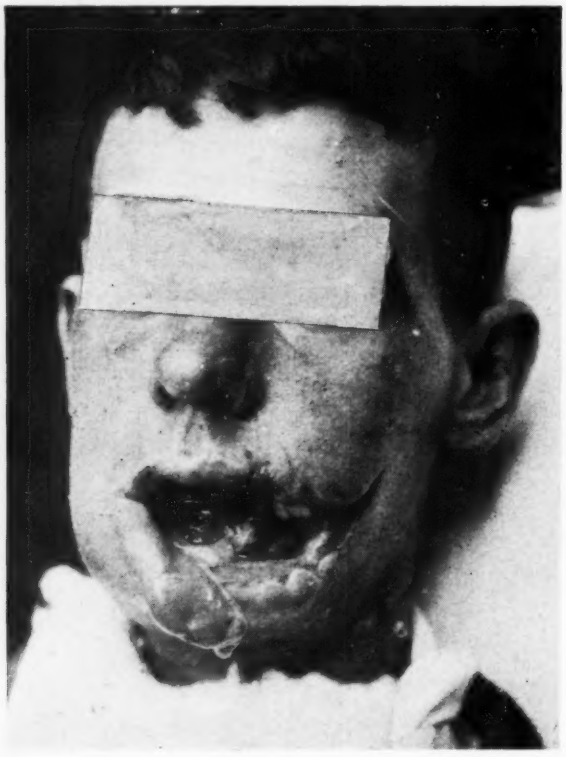


Fig. 22.—Appearance of the patient twelve days after admission to the hospital. At this date the fractured mandible was immobilized. Note the size of the wound which is greatly reduced in size (Case 6).

Remarks.—Even though this patient had considerable loss of bony tissue at the anterior section of the mandible, the remaining posterior segments of bone were immobilized in their proper positions with provision for a vulcanite support for the missing tissue. Not until the framework of the lip was adjusted were the lips sutured and then held in position by the splint and its vulcanite support. By this procedure future reconstruction work is simplified.

CASE 6 (O).—This patient was wounded on April 21, 1917, and was admitted to the hospital on April 25, 1917. There was a wound about three inches long on the left side of the face, lacerating the angle of the mouth, the lower lip, the tongue,

and the submaxillary region. In the upper jaw, the teeth and the alveolar process from the right cuspid to the left second molar were fractured and very loose. The comminution of the lower jaw extended from the angle on the right to the left second bicuspid region, but the left bicuspids and molars were destroyed. At least four pieces of bone of appreciable size (the remnants of the lower border of the mandible) remained and were pulled downward toward the base of the tongue (Figs. 20 and 21).

On April 29, 1917, four days after admission, the wound was debrided, and the mouth cleaned of isolated bone and teeth fragments.

Fig. 23.—X-ray showing method of immobilization in Case 6. A stout arch wire was fastened to the exposed ends of the posterior fragments and to it the anterior fragments were raised and suspended by means of fine wires passed through holes at the exposed ends of the displaced fragments. Three weeks later this splint was discarded as there was sufficient firmness of the anterior fragments and an interdental vulcanite splint was used. Ultimate consolidation of bone followed (Case 6).

May 1, 1917, impressions of the teeth were taken for splints. On May 5, 1917, ten days after admission to the hospital, at 2 P.M., the patient had a hemorrhage from the left side of the lip. May 7, 1917, twelve days after admission, the patient was operated upon, and the fractured mandible immobilized by a band-and-arch wire splint. The splint was fastened to the exposed ends of the existing posterior fragments and thus held the posterior fragments in their original positions. It was also necessary to bring the badly displaced median fragment of bone into alignment. To accomplish this, a hole was drilled through the exposed end of each fragment of bone; a fine wire was passed through the hole and each fragment of the bone was raised to position and suspended to the arch wire of the metal splint (Figs. 22 and 23).

On May 9, 1917, fourteen days after admission, the patient was operated upon and the facial wound was sutured (Fig. 24). July 17, 1917, a new splint and chin piece was placed in position.

On Oct. 11, 1917, the patient was operated upon and the tongue was released and elongated by cutting its adhesions.

Fig. 24.

Fig. 25.

Fig. 24.—Fourteen days after admission, the patient was operated upon, and the facial wound was sutured (Case 6).

Fig. 25.—Appearance of patient at the time of evacuation to England (Case 6).

The remains of the mandible, which was brought to alignment, have consolidated. In this case also the mandibular arch is shortened anteroposteriorly, but the deformity is slight. At different times bony sequestra have been removed as they appeared or began to loosen. After the removal of the original lower appliance with the wire sutures, the chin showed a slight tendency to recede, and a screw was placed in the bone at about the median line. By means of an extraoral appliance the mandibular arch was again pulled forward. Upper and lower dentures have been supplied (Fig. 25).

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SOME DEFORMITIES OF THE FACE AND THEIR CORRECTION

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FACIAL deformities assume importance from several viewpoints, namely: functional, psychologic, cosmetic, vocational, and economic. Their correction has received periodic attention since early authentic surgical history. Rhinoplasties were done in India as early as 1000 B.C., and later in Italy, especially by the Branca family of Catania, and by Gasparo Tagliacozzi of Bologna in the sixteenth century. Interest was again aroused (1816 to 1847) by von Graefe and Dieffenbach during the time they were professors of surgery in the University of Berlin, and has continued to increase steadily.

Bone grafts were used to correct depressed nasal deformities in 1896. Rib cartilage transplants were used early in the twentieth century and continue to be more and more frequently employed.

Plastic and reconstructive surgery was given its greatest impetus during World War I. Since that time the technique has been refined and many of the methods then devised have been improved, and now play a still more important role in the surgical repairs necessitated by the present world-wide conflict.

The most frequent congenital deformities of the face are those associated with the various types and degrees of cleft lip and cleft palate. The methods which we prefer for the correction of such deformities have been considered in detail in several previous communications, thus they will be omitted here.

The splendid blood supply to all facial structures, and the mobility of the superficial tissues, make this area one especially well adapted to many types of plastic and reconstructive procedures.

Pigmented nevi may be major disfigurements, sufficient to exert dominant influences upon an individual's mental attitude, and upon the social and economic outlook. Fortunately most of them are amenable to surgical measures which make the areas relatively inconspicuous. The blue-black melanotic mole must not be irritated or manipulated, and, if it is to be removed, only a wide excision should be considered. In the brown or brownish hyperkeratotic or hairy varieties, however, lines of excision may with safety be made in or near the margins, the surrounding skin undermined and then approximated to cover entirely

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A.

B.

C.

Fig. 1.—M. D., Case H-1144, aged 3 years. *A*, Papillary pigmented hairy nevus. *B*, Appearance two years later, after excision of frontal portion of nevus and use of a full-thickness skin graft, and partial excision over maxillary region, undermining margins and approximation without skin graft. *C*, Appearance one year later, five months after excision of remnants of pigmented area, and use of a calibrated split-skin graft, 0.012 inch in thickness, taken from the infrascapular region. The margins of the split-skin graft can be still further improved.

the raw area. This applies to medium-sized nevi. If the pigmented area is too large to permit this procedure for complete removal at one operation without undue tension on sutures, it may be removed by two or more such excisions, undermining of skin, and reapproximations by advancement of skin edges. The hairy pigmented area shown in Fig. 1 was so large that skin grafts, in addition to excisions, were used as described in the legends—a full-thickness graft in the frontal and temporal areas, and a calibrated split-skin graft to the infraorbital and cheek regions. Whenever possible, excision and advancement of the surrounding skin should be the method of choice, since skin grafted from some distant donor site never has exactly the same color and texture as that of the adjoining skin. Grafts from distant areas, however, are in many cases methods of necessity.

A. *B.*

Fig. 2.—C. B., Case H-1272, aged 29 years. *A*, Lupus vulgaris which began in early childhood. *B*, Appearance nine months after excision of the skin of the entire involved area and the immediate use of a calibrated split-skin graft 0.014 of an inch thick, removed from the infrascapular region by means of a Padgett dermatome.

The case of lupus vulgaris shown in Fig. 2 began in very early childhood. Several types of treatment, chiefly radium, x-ray, and electric needles, were given throughout the intervening years without any appreciable improvement. A result which we regard as highly satisfactory was obtained by complete excision of the involved area and immediate skin grafting, using a calibrated skin graft 0.014 of an inch in thickness, taken from the infrascapular area by means of a Padgett dermatome. Six weeks after grafting, daily gentle massage of the area was begun. Examination nine months later showed that there had been a definite increase in the thickness of the graft and in the amount of subcutaneous fat.

There is a rather wide range of ear contours which come within the classification of normal. The size and shape of normal ears show hereditary characteristics in races and in families, which are as striking as are those found in the anterior facial features. Heredity also plays a part in some ear contours beyond the range of normal. Such abnormal contours may be unilateral or bilateral.

There are two classes of protruding or prolapsed ears which we believe should be treated by plastic surgery. First, those cases in which the deformity is so great that it interferes, or probably will interfere later, with the individual's success in securing satisfactory employment in the vocation of his choice. Second, those cases with less marked deformities, but occurring in sensitive individuals who are made so unhappy by being teased about their appearance that they tend to become

A. *B.* *C.*

Fig. 3.—P. B., Case H-1111, aged 7 years. *A*, Bilateral prolapsed protruding ears. Note deficiency of anthelix folds. *B*, Appearance eighteen months after reconstruction by the method shown in Fig. 4. *C*, Appearance nineteen months after secondary adjustment of superior portion of ears (aged 10 years). The striking change in personality is interesting.

self-conscious, secluded, and introspective. These deformities are chiefly due to insufficiency, or even absence, of the anthelix fold. To secure a satisfactory cosmetic result, an anthelix fold must be established. The result shown in Fig. 3 was gratifying not only because of the improvement in the appearance of the ears but also because of the definite transformation in personality obtained. The semidiagrammatic sketches and their legends (Fig. 4) give the technique used. Individual operators have devised their own modifications in technique according to the degree of the ear deformity being corrected, but all of the better operations are really founded upon the basic principles described by W. H. Luckett.* With near-normal contour restored, and approximately a 30 degree cephaloauricular angle established, the ear ceases to be conspicuous even though it may still be somewhat above the average size.

*Luckett, W. H.: Surg. Gynec. & Obst. June, 1910.

Marked congenital deficiencies of the nasal bones and the frontonasal processes of the maxillae are preferably corrected at 17 to 20 years of age by autogenous rib cartilage transplants (Fig. 5). If correction is attempted in *childhood* the *transplanted cartilage* usually does not in-

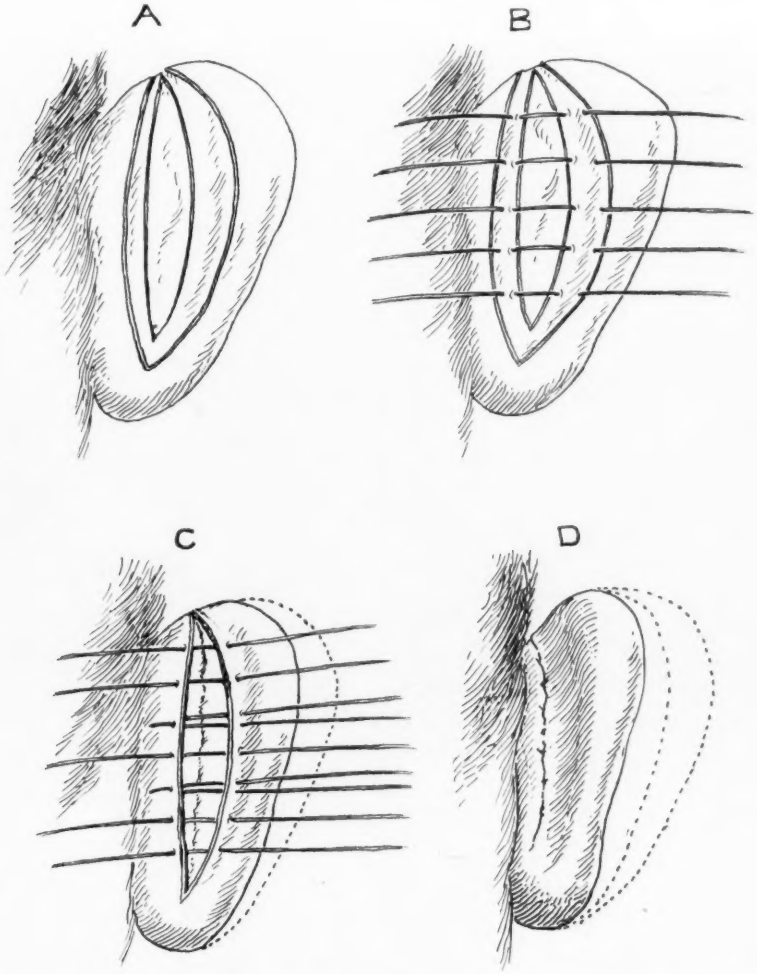


Fig. 4.—Semidiagrammatic sketches showing: *A*, The incisions used for removal of skin from the dorsal surface of the ear; the smaller ellipse shows approximately the amount of cartilage removed. *B*, Manner of inserting small catgut sutures through the perichondrium which, when tied, will force the cut edges of the cartilage anteriorly, forming an anthelix. *C*, Surfaces of cartilage have been approximated and skin sutures inserted; outer dotted line shows original position of the margin of the ear. *D*, Shows skin margins approximated, and the resulting outline of the ear. Outer dotted line marks original position; inner dotted line shows the position after approximating the cartilage.

crease appreciably in size and, consequently, as maturity is approached there is an increasing disproportion between the size of the transplanted cartilage and the size of the developed face. If, in some cases, early correction (Fig. 6) is deemed advisable because of marked introspection, or other psychologic reason, the patients and their parents should be told that a second operation may be necessary during late adolescence.

The use of curved cartilage chisels of proper sizes greatly facilitates obtaining the cartilage for transplanting, and placing the smooth convex surface upward helps to insure a well-formed dorsum nasi. The cartilage is preferably inserted through a columellar incision. Nasal

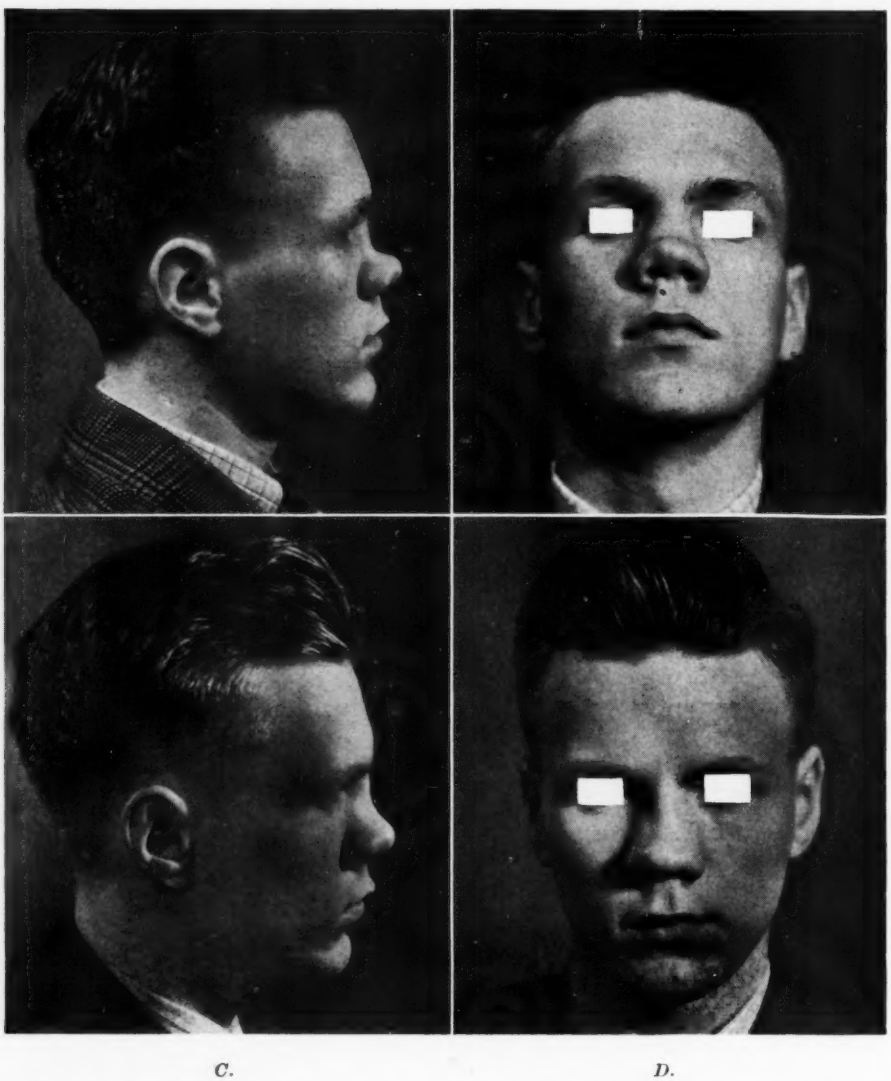


Fig. 5.—Case 6747, aged 17 years. *A*, Marked nonsyphilitic congenital deficiency of the nasal bones and frontonasal processes of the maxillae. *B*, Front view of *A*. *C*, Profile contour of nose four months after rib cartilage transplant. *D*, Front view of *C*.

depressions from destruction of the septal cartilage by infected septal hematomata in childhood, those from too extensive submucous resection of the nasal septum, and those from marked trauma are rather similarly corrected, but are more apt to require a supporting cartilagenous post

in the columella, extending from the undersurface of the anterior end of the dorsum transplant to the intermaxillary spine.

Excess convexities of the dorsum nasi are usually associated with some elongation and drooping of the nasal tip. Corrections are made by freeing the overlying skin and subcutaneous tissues from the cartilagenous bridge, and the periosteum from the bone to be removed, through an incision made within the superior portion of the anterior

Fig. 6.—D. W., Case H-1484, aged 5 years. *A*, Congenital nonsyphilitic deficiency of the nasal bones and frontonasal processes of the maxillae. *B*, Profile view of *A*. *C*, Contour of nose six months after autogenous rib cartilage transplant. *D*, Profile view of *C*. *E*, Contour of nose eight months after *C*. *F*, Profile eight months after *D*. Measurements and contour of nose indicate that the transplanted cartilage is growing as rapidly as the original nasal structures.

nares. In most instances we prefer to remove the excess convexity by means of numerous rasps in assorted shapes and sizes. Bone dust is removed with meticulous care; no rasp having been used is reinserted into the field of operation until it has been carefully brushed and cleansed in sterile water. In some instances saws are preferred in removing very large humps (Fig. 7). In most cases the width of the

new dorsum can be sufficiently narrowed by rasping the anterolateral portions of the frontonasal processes of the maxillae while they and the remnants of the nasal bones are being rounded and smoothened. If the

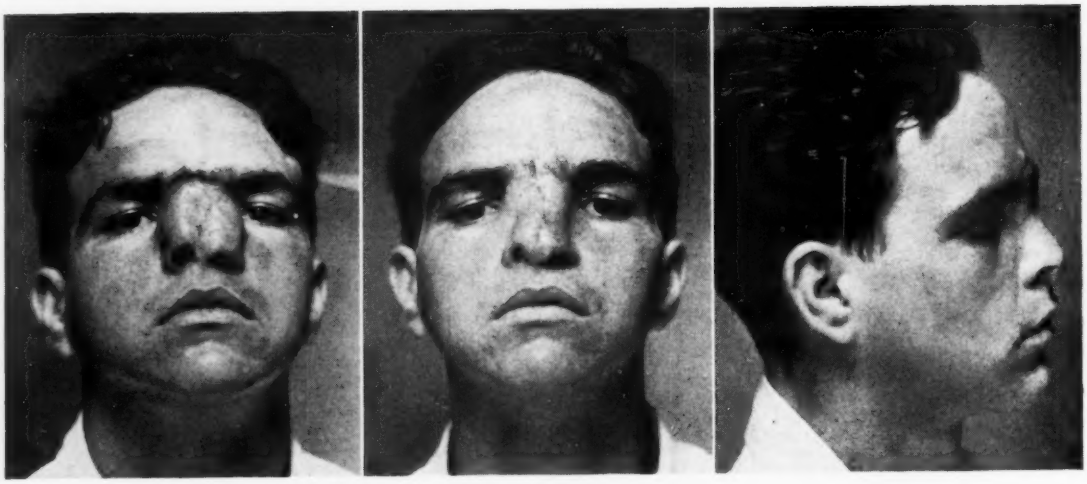
Fig. 7.—E. S., Case H-1737, aged 23 years. *A*, Profile showing convexity of dorsum and elongated drooping tip of nose. *B*, Front view of *A*, showing contour of nostrils. *C*, Profile six weeks after removal of excess convexity, shortening and elevating nasal tip. *D*, Front view of *C*, showing contour of nostrils.

width of the new dorsum is too great, the frontonasal processes may be divided with a saw, or narrow chisel, near their attachment to the bodies of the maxillae, and then pressed medially to the desired width. After

freeing the columella from its attachment to the septal cartilage by a through-and-through incision, a triangular section of the cartilage of the necessary size to secure the desired degree of shortening is removed and the columella then sutured to the septum in the position which properly elevates the tip.

Fig. 8.—B. B., Case H-1502, aged 68 years. *A* and *B*, Rhinophyma, twenty-six years in developing. *C* and *D*, Appearance two months after multiple elliptical excisions, two operations, one month apart.

A *rhinophyma,* even of marked degree (Fig. 8), may be trimmed down to approximately normal size and contour by multiple, deep elliptical excisions, first removing the nodules, and then as much of the remaining



A. *B.* *C.*

Fig. 9. (*For legend see opposite page.*)

A. *B.* *C.*

D. *E.* *F.*

Fig. 10. (*For legend see opposite page.*)

redundant tissue as the individual case may require. When the skin margins are approximated, healing is surprisingly rapid and the scarring relatively inconspicuous. Two operations, one or two months apart, are usually required. Should some undue thickening of the epidermis still remain around some of the larger pores, it can be minimized by a series of applications of a saturated solution of trichloracetic acid over several small areas at one time, and repeated over other similar areas at ten-day or two-week intervals until the surface is fairly smooth and even.

Nasal chondromas usually produce both external and internal deformities. Treatment calls for excision and plastic reconstruction (Fig. 9).

Loss of external nasal soft tissue is preferably repaired by skin from nearby areas, because the color and texture matches more closely than if taken from any distant point. If the area is small, the surrounding tissue may be undermined and advanced. If slightly larger, then immediate or delayed pedicled flaps from the nasolabial folds, which are very mobile and have splendid blood supply, are used.

In a case where there is marked loss of nasal tissue, the use of a delayed pedicled flap from the frontal area is sometimes the method of choice, at other times the method of necessity, in reconstruction. Fig. 10 shows the photographic record of a case of basal-cell epithelioma in which this method of rhinoplasty was used after wide excision of the involved tissues.

Loss of tissue from the superior portion of the upper lip, with or without an accompanying loss about the floor of the nostril, in many instances can be replaced advantageously by an advancement of a rectangular flap, single or double epithelized as may be required (Fig. 11).

Cavernous hemangiomatous areas about the lips, eyelids, or cheeks which are primarily treated surgically by excision and plastic reconstruction have shown, in our series, better cosmetic results, especially in adults, than those treated by radiation alone, or by radiation followed by plastic repair. In the cases in which the eyelids are involved, as in Fig. 12, adequate radiation probably would carry with it some risk of damage to the eyeball structures.

Fig. 9.—R. S., Case H-919, aged 19 years. *A*, Deformities due to congenital nasal chondroma. X-ray studies show that the marked widening of nasal structures extends into the nasal septum, giving it the appearance of a large "Y." *B*, Appearance eighteen months after excision of a large portion of the dorsum of the nose by wide elliptical incisions extending from midfrontal area to below tip of nose, complete removal of chondroma, division of frontonasal processes of maxillae near their attachments and bringing them to more medial positions, thus narrowing the new dorsum nasi. *C*, A three-quarter view of nose eighteen months after operation.

Fig. 10.—H. B., Case H-1621, aged 56 years. *A*, Basal-cell epithelioma of nose, 15 years' duration. Recurrences after electrical treatments and small excisions on several occasions. *B*, Showing extent of involvement about nares. *C*, Nasal structures were excised wide of all involved areas, then reconstructed by delayed pedicled frontal flap, with double epithelized distal portion. Area from which flap was taken was immediately covered with split-skin graft. Photograph shows appearance nineteen days after nasal reconstruction. Base of pedicle was returned to original position the following day. *D*, Profile of *C*. *E* and *F*, Appearance of nasal and frontal areas one year after *C* and *D*. (There was no recurrence of basal-cell lesion, three years after excision of nasal structures.)

A. *B.*

Fig. 11.—R. W., Case 5146, aged 34 years. *A*, Opening entirely through lip, resulting from the removal of a mole by radium seven months previously. During that time the surrounding margins showed no tendency toward healing. Biopsy negative for malignancy. *B*, Showing appearance of lip seven months after plastic repair. The margins of the opening through the lip were excised, converting it into a square. Parallel incisions were carried from the lateral corners of the opening, through the full thickness of the lip and anterior portion of the cheek to the points indicated by the remaining scars. The pedicle flap thus formed was advanced and sutured with meticulous care into new position, entirely closing the opening.

A. *B.*

Fig. 12.—H. H., Case 8058, aged 45 years. *A*, Cavernous hemangioma, present since infancy. *B*, Appearance seven weeks after a two-stage operation. Excess tissue on skin surface first removed. Conjunctival adjustment one month later.

SUMMARY

Several widely varying types of deformities of the face have been presented. The operative procedures used have been briefly described and the results obtained shown by illustrations from unretouched photographs.

In planning plastic reconstruction, one should carefully study the problems presented, endeavoring to visualize the ultimate result desired and to outline accordingly the various steps necessary in securing the best possible repair. Knowing the number of contemplated operations and the probable length of the intervals helps the patient in arranging adequate time for operations and convalescence.

Accuracy in outlining flaps, care in the preservation of the best possible blood supply, gentleness in handling tissues, and evenness in the approximation of subcutaneous tissues and skin margins, all tend to minimize scar tissue and thereby assist in securing the best functional and cosmetic results.

THE REPAIR OF BONY AND CONTOUR DEFORMITIES OF THE FACE

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DISPLACEMENT or loss of supporting structure of various parts of the face as a result of faulty development, injury, disease, or operation is accompanied by impairment of function and appearance. The principal facial deformities of developmental origin are cleft palate, unshapely contour of the external nose, and malrelationship of the upper and lower jaws resulting in undue prominence or recession of the chin, open bite, and other disturbances of occlusion of the teeth. Acquired deformities involve displacement or loss of supporting tissues (bone and cartilage), as well as overlying soft tissues, of varying extent, causing cosmetic or functional disturbance or both.

The means at our disposal for the replacement of lost or displaced supporting tissues following injury, disease, or operation are the use of soft tissue flaps, cartilage, bone, fascia lata, dermal grafts, and artificial appliances. Some bony defects accompanied by soft tissue loss can be satisfactorily repaired with soft tissue flaps alone when the bone loss involves an immovable part such as the hard palate or the outer surface of the maxilla. In the smaller palatal defects, sliding or pedicle flaps of oral or nasal mucous membrane may be used, while for the larger ones the introduction of pedicled flaps of skin may be necessary. Where a large bony defect is accompanied by loss of skin or mucous membrane on both sides, both epithelial surfaces should be replaced. Artificial substitutes are sometimes necessary to replace losses of bone and soft tissues of the upper jaw, being more satisfactory than surgical restorations under some circumstances. In some cases of palatal defect, for example, it may be possible to close the opening by surgical means, but the tissues thus repaired do not afford satisfactory attachment for artificial dentures. Artificial substitutes are occasionally preferable in external defects about the face where the extent of the tissue loss or the age of the patient militates against satisfactory surgical repair.

For the deeper and more extensive contour defects of the frontal region, nose, cheek, chin, or other parts of the face, costal cartilage forms the most satisfactory replacing substance. Several foreign materials (such as celluloid and ivory) have from time to time been advocated for this purpose. They have an advantage in that they are easily inserted without mutilating other parts of the body, but they are subject to all the disadvantages of any foreign body; for example, extrusion is

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possible at any time. At one time paraffin was extensively used, but it should have no place in plastic surgery of the face, as it is difficult to control in injection, sometimes causing unsightly disfigurements, undergoes changes in shape, and may cause embolism and tumor formation. In late years, vitallium and, more recently, tantalum have been used with encouraging results. Transplanted bone as a support for the bridge of the nose is employed successfully by some surgeons. We prefer costal cartilage for this purpose, because it rarely undergoes absorption when imbedded in soft tissues and is not so susceptible to infection as bone. Costal cartilage is not difficult to obtain in almost any quantity desired and is easily trimmed to suitable size and shape. While living autogenous costal cartilage is undoubtedly preferable to any other, in recent years many operators have successfully used preserved cartilage from other individuals and even from cadavers. The use of preserved cartilage has the advantage in that unlimited quantities are available, and the patient does not have the inconvenience of the chest operation added to that on the face. Living autogenous cartilage, on the other hand, is less likely to undergo changes after transplantation. Costal cartilage has a tendency to change shape by curling, resulting in an unsightly deformity. To overcome this, Gordon New exposes the cartilage after removal to live steam for a minute or two. This causes the maximum amount of curl to take place immediately, after which the cartilage can be trimmed to proper size and shape and no further changes will occur. Of course, the steaming destroys the vitality of the cartilage. Costal cartilage does not form a firm union with bone; hence, it cannot effect a stable restoration of continuity in a movable bone such as the mandible. For filling gaps to restore continuity of the mandible, bone transplants alone are satisfactory.

Displacement of bony structure alone, or combined with loss of substance, may be responsible for facial deformity. In some cases of this type, correction of the deformity may be attained by mobilization of the displaced portion of bone and replacement in normal position. This is not always possible, especially where the displacement is of long standing, such as in the case of an old depressed fracture of the nasal or malar bones. Here, correction is more satisfactorily brought about by building out the contour with added bone or cartilage at the site of the depression.

After a fracture of the mandible, with or without loss of substance, union may take place with shortening at the site of fracture, resulting in facial asymmetry and functional disturbance. The same sort of deformity may follow loss of a portion of the mandible from necrosis or operation for removal of a neoplasm. Here, the displacement first must be corrected by osteotomy at the site of malunion or division of adhesions holding displaced fragments in a contracted position, and by reduction of fragments to a position as normal as possible, followed later by

bone grafting if a gap remains that is too wide to be bridged by spontaneous bone regeneration.

Osteotomy of the mandible may be carried out with a narrow chisel at the site of malunion but is usually done with less trauma by means of a Gigli saw. A small incision through the skin, not more than one-half inch long, is made to the lower border of the mandible at the point of malunion. A full-curved pedicle needle is passed through the incision, close to the inner surface of the bone, until the mucous membrane of the mouth is pierced. By means of a wire through the eye of the needle, a Gigli saw is carried on the inner surface of the bone with one end in the mouth and the other emerging through the skin incision. The mandible is then sectioned with the saw from the inner side out through the fracture line. The skin incision is sutured and usually heals by first intention, leaving practically no visible scar. The bone fragments are now reduced and treatment is as for a recent fracture, with or without loss of substance. The method of fixation of the fragments to be used depends upon the availability of teeth. In most patients with sufficient teeth in each fragment and in the upper jaw, we find that simple wiring methods, such as the eyelet or the arch bar methods, are most easily applied and give adequate fixation. The more elaborate splints are reserved for patients in whom teeth are not adequate for use of the simpler methods.

Bone grafting is sometimes employed for repairing defects of the cranium and contour losses of various parts of the face, but its most frequent use is in restoring continuity and replacing losses of substance of the mandible resulting from trauma, necrosis, or resection for treatment of disease.

Statistics from World War I indicate that about 11 per cent of gunshot fractures result in nonunion and require bone grafting. The nonunion is caused principally by the large loss of bone substance and inability of the repair mechanism to bridge the gap when the collapsed fragments are drawn apart and fixed in proper position. The loss of bone is not so often due to primary destruction as to extensive shattering followed by infection and necrosis. In comminuted fractures, proper early fixation and conservation of viable bone fragments will do much to render bone grafting unnecessary later.

The object of treatment in patients with loss of substance of the mandible from whatever cause is primarily restoration of the function of mastication. This is attained by restoring the normal occlusion of the remaining teeth and stabilizing the jaw by filling in the lost continuity of the bone. A secondary objective is the building out of contour of the face for improvement in appearance. In patients with loss of substance it is very rarely desirable to obtain union by bringing the ends of the fragments together, sacrificing the occlusion of the teeth. This results in a crippling of the masticatory function and an increase in the external deformity.

Where bone grafting is contemplated, the preoperative treatment of patients with losses of substance of the mandible is as follows: removal of all septic foci, reduction, and fixation in such a position that the normal occlusion of the remaining teeth is restored. Septic foci include roots of teeth projecting into the area of lost substance, other teeth showing evidence of periapical or periodontal disease, bony sequestra, metallic foreign bodies, and infection in the adjacent soft tissues. No operation to restore the continuity of the bone should be attempted until all sources of infection have been removed and until at least three months have elapsed after all sinuses and septic wounds have healed.

Reduction is brought about in cases of nonunion by manipulation, followed immediately by the application of wires to fix the upper and lower teeth together, or, if the existing teeth are not adequate for this method, then the more elaborate interdental splints are used. Where the bone fragments are not freely movable and cannot be reduced by manipulation before application of measures of fixation, owing to the presence of fibrous adhesions, it becomes necessary to sever these adhesions at a preliminary operation, apply the fixation, and then wait several weeks for healing of the soft tissues to occur before performing the bone-grafting operation. As long as there is any possibility of contamination of the wound with oral secretions, bone grafting is contraindicated. In nearly all cases of this type the preliminary operation requires cutting through the oral mucosa, which renders absolutely necessary postponement of the bone grafting until complete healing has occurred.

Types and Methods of Bone Grafting in the Mandible.—In many of the patients after World War I restoration of continuity was brought about by a pedicled graft from the mandible itself, the pedicle consisting of attached muscle. This method was first described by Bardenheuer in 1893 and was popularized by Cole, of London. We have not used this method recently because we found that it produces undue distortion of the soft tissues of the floor of the mouth and neck and is not suitable for large losses of bone substance, especially in the region of the angle and ascending ramus of the mandible. We consider also that the cortex of the tibia is not very suitable as a source of bone graft for the mandible because of its extreme density and consequent resistance to penetration of new blood vessels in the process of consolidation. Also, fracture of the tibia after removal of a thick graft is not unknown. Rib grafts have sometimes been used for these defects but are usually too thin. During the past twenty-four years we have limited ourselves to two methods, each having fairly definite indications; namely, the osteoperiosteal graft from the tibia and the graft from the crest of the ilium.

1. *The Osteoperiosteal Method of Delagenière:* The osteoperiosteal graft contains all the elements necessary for osteogenesis, is flexible, and is easily adjustable to the size and shape of the defect. The tech-

nique of removal and insertion is simpler than that of any of the other methods. It causes no disability in the leg. It requires longer to obtain complete consolidation than by other methods, and no dependence, of course, can be placed on the rigidity of the graft itself for maintenance of the mandibular fragments until consolidation has occurred. While this form of graft can be used for losses of substance of the mandible of almost any extent and any position, we usually reserve it for defects of 2 cm. or less and for patients in whom the external contour of the face shows little or no deficiency. It is also to be selected for use in children, because the crest of the ilium shows very little ossification before 15 or 16 years of age.

2. *Graft From Crest of Ilium:* A graft from the crest of the ilium was first used in Germany by Lindemann and was the method of choice also of Gillies and his co-workers at the Queen's Hospital at Sidcup, England. This type of graft is preferred if the gap in the mandible exceeds 2 cm., and especially if the external contour of the face shows the deficiency. The crest of the ilium furnishes a large piece of bone of porous structure closely resembling that of the mandible, it is easily penetrated by new vascular supply, and it can readily be cut to suitable shape. The disability produced by removal of the graft is quite temporary and the danger negligible.

The technique of grafting the mandible by either of these methods has been fully described elsewhere, so further space will not be taken up with it here, except to say that exposure and preparation of the mandibular fragments are done before removal of the graft from the donor site in order that the size of the graft required may be determined and also on account of the possibility of opening into the mouth while preparing the bed for the graft, an accident that would render useless the application of the graft at this time. Another reason for this order of procedure is the desirability of protecting the viability of the graft by placing it in its new position as soon as possible after removal from its original site.

Postoperatively, fixation of the jaws must be maintained until consolidation is well advanced; that is, for at least eight weeks. Regeneration may be checked by x-ray examination at monthly intervals, but the final test of consolidation is by clinical examination after disconnecting the upper and lower teeth.

The following cases illustrate several of the features mentioned in this article:

CASE 1.—In Case 1 is illustrated protrusion of the mandible. The patient was first seen at the age of 18 years in consultation regarding a protrusion of the mandible which had gradually become more noticeable with growth. Physical examination revealed nothing having any bearing on this condition. The lower anterior teeth were about three-fourths of an inch in front of the corresponding upper teeth, and only the last molars were in occlusion (Fig. 1). The forward position of the mandible caused a very noticeable prominence of the chin (Fig. 2). There was

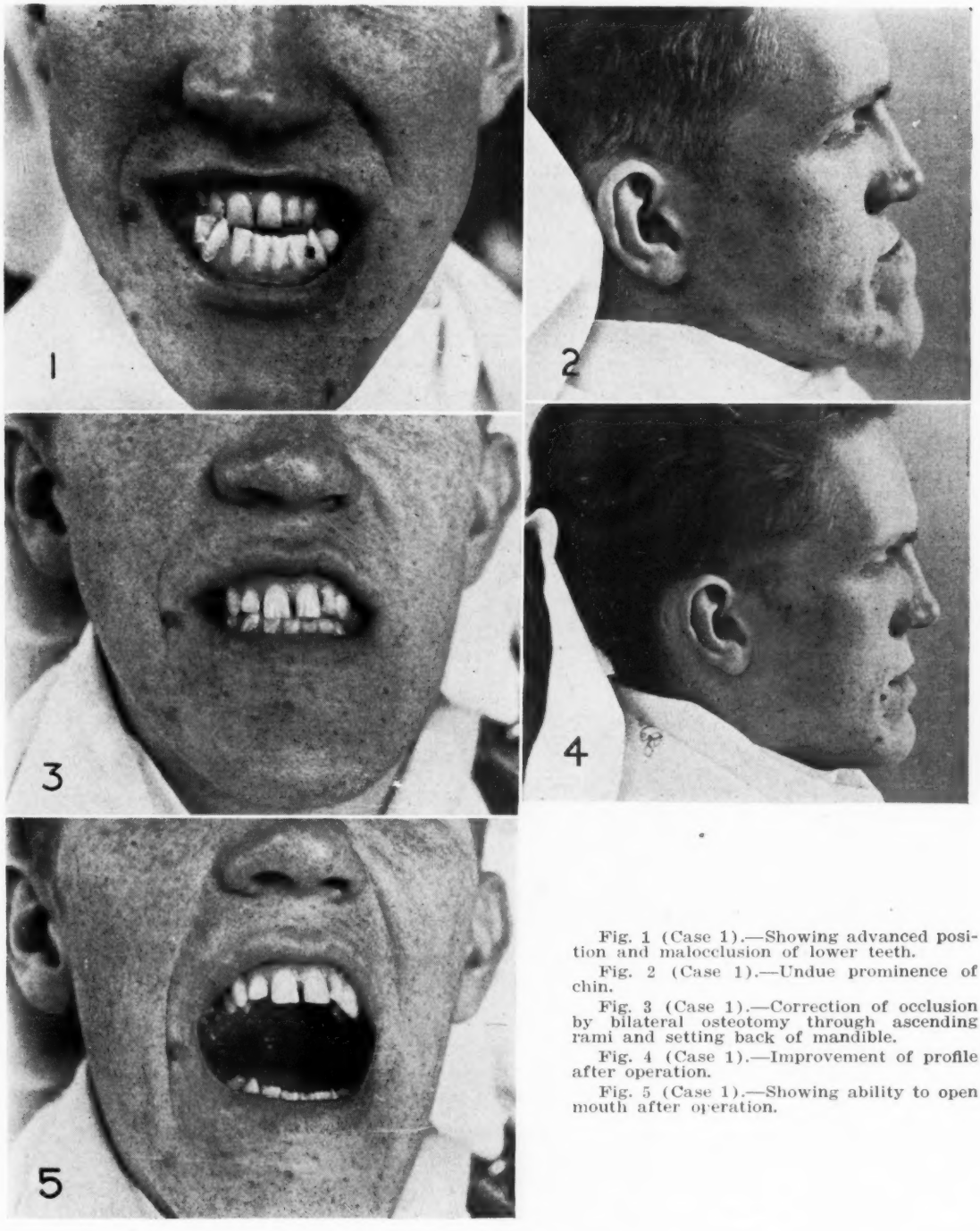


Fig. 1 (Case 1).—Showing advanced position and malocclusion of lower teeth.

Fig. 2 (Case 1).—Undue prominence of chin.

Fig. 3 (Case 1).—Correction of occlusion by bilateral osteotomy through ascending rami and setting back of mandible.

Fig. 4 (Case 1).—Improvement of profile after operation.

Fig. 5 (Case 1).—Showing ability to open mouth after operation.

marked interference with the function of mastication. Impressions were made of the teeth and plaster casts prepared to determine whether a satisfactory dental occlusion could be obtained by setting the mandible back. This being found possible, an operation was decided upon. Preceding the operation, half-round arch bars were

applied to the upper and lower teeth to serve for postoperative fixation. Under intratracheal ether anesthesia introduced through the nose, each ascending ramus of the mandible was sectioned horizontally by a Gigli saw introduced through small skin incisions behind and in front of the ramus by means of a modified Blair pedicle needle. This permitted the main part of the mandible to be slid back on these cuts, bringing the lower teeth into good occlusion with the upper. The upper and lower teeth were then fixed in occlusion by connection of the arches on the teeth with tie wires. Immobilization was maintained for six weeks, after which union in the new position was found to be fairly solid. The wire fixation was replaced by intermaxillary elastics for about ten more days, the patient being then discharged. Figs. 3, 4, and 5 illustrate the result of the operation.

CASE 2.—In Case 2 is illustrated the use of costal cartilage to restore contour in the frontal region. The patient sustained a crushing injury in an automobile accident with loss of bone in the left frontal region. This left him with a marked depression, the overlying skin being intact except for a vertical scar (Fig. 6). An

Fig. 6 (Case 2).—Marked depression left frontal region due to loss of bone.
Fig. 7 (Case 2).—Elimination of depression by implantation of costal cartilage.

incision was made through the old scar line and the skin on each side undermined over the depressed area to form a pocket. Into this was inserted a piece of autogenous costal cartilage of suitable size and shpae to restore the contour of the forehead. The skin wound was closed with interrupted silk sutures (Fig. 7).

CASE 3.—In Case 3 is illustrated a contour defect of the right frontal region with loss of both soft tissues and bone. The patient was thrown from a moving automobile into the road, where he landed on his face, resulting in a compound comminuted fracture of the right side of the frontal bone with avulsion and laceration of overlying soft tissues. Fig. 8 shows the condition of the patient several months later when the defect was ready for definitive repair. On the right side of the forehead there was a broad deep defect, involving the bone in part, covered with healed scar. One small area had been covered with unsightly pinch grafts, no doubt to hasten healing. There was a small opening into the frontal sinus. The extent

Fig. 8 (Case 3).—Healed deformity of right frontal region. Loss of bone and soft tissue with opening into frontal sinus.

Fig. 9 (Case 3).—Stage in transfer of tube pedicle flap from clavicular region for repair of forehead defect.

Fig. 10 (Case 3).—Another stage of transfer of flap to forehead.

Fig. 11 (Case 3).—Another stage of transfer of flap.

Fig. 12 (Case 3).—Flap spread out to cover forehead defect.

Fig. 13 (Case 4).—Extensive brown hairy nevus of left side of face.

Fig. 14 (Case 4).—Tube pedicle flap on abdomen with one end attached to wrist for later transfer to face.

Fig. 15 (Case 4).—Tube pedicle flap from abdomen carried to left side of face on right wrist.

Fig. 16 (Case 4).—Result after excision of growth and covering of raw area with tube pedicle flap from abdomen.

of the area precluded repair by sliding flaps from the surrounding frontal region. The depth of the defect and the opening into the frontal sinus rendered a free skin graft unsuitable. Consequently, a tube pedicle flap from the right clavicular region was transferred to the forehead in several stages at three-week intervals. The procedure is shown in Figs. 9, 10, and 11. Fig. 12 shows the final stage of the flap transfer. Later, the eyebrow was restored by a free full-thickness graft from the scalp.

CASE 4.—Brown hairy congenital nevus of face had existed since birth in the patient in this case, and the boy was presented for treatment at 6 years of age. The lesion was dark brown in color and slightly elevated; the surface was rough and covered for the most part with a heavy growth of furlike hair. It involved the entire left cheek, extending into the temporal region, the entire lower eyelid and part of the upper eyelid, the left side of the nose, including the ala, and passed over on to the right side of the nose (Fig. 13). These growths are not radio sensitive, and surgical excision in this case offered the only possibility of successful treatment. Three ways of repairing the defect were considered: (1) Multiple partial excision. In growths and scars involving a moderate area in the cheek, this method is excellent in that it gradually advances the surrounding healthy skin and succeeds in covering the area with skin of texture and color normal for the part, with a very small amount of scarring. In the present case, the extent of the area involved precluded the use of this method. (2) Complete excision, followed by immediate application of a split-skin graft. This was also rejected, partly because of the inability of a free graft to furnish sufficient contour, and also the appearance of the grafted area would leave too much to be desired. (3) Use of a pedicled flap. This method was finally selected, because it supplied sufficient contour, with a better chance of complete take of the transplanted tissue. It was realized that there would be difficulty in matching the rest of the face in color and texture. At the first operation a tube pedicle was prepared on the left side of the abdomen from a strip of skin and subcutaneous tissue three inches wide and eight inches long. Three weeks later the lower end of the tube was cut loose and sutured into a raw area exposed by turning a flap on the radial side of the right wrist (Fig. 14). Restriction of movement during healing was adequately managed by means of adhesive plaster strips. The next step, three weeks later, consisted in disconnecting the upper end of the tube from the abdomen and carrying it up on the wrist to the face where it was sutured into a raw area in the left temporal region created by excision of part of the nevus. Sufficient fixation for good healing was obtained by holding the arm in the Velpeau position with adhesive plaster and a bandage. Plaster of Paris was unnecessary (Fig. 15). After a further three-week period the flap was disconnected from the wrist and the tubed portion opened out and spread to cover the raw area on the face after excision of the major portion of the growth. Two or three further operations were necessary to smooth edges here and there, and a full-thickness preauricular skin graft was applied to the left lower eyelid. Although there is some discrepancy in color and texture of the skin of the flap as compared to the rest of the face, it is hoped that with time this will become less noticeable (Fig. 16).

CASE 5.—In this case is illustrated the deformity of contour of the face and interference with function due to malunion in a fracture of the mandible. The patient was edentulous and sustained a fracture of the left ascending ramus of the mandible. Owing to the absence of teeth, no reduction or fixation was applied after the injury, with the result that his fracture united in malposition, the left side being shortened. This caused the chin to deviate to the left. The mouth opening was greatly restricted, and this and the malrelation of the upper and lower alveolar arches prevented the wearing of artificial teeth (Figs. 17 and 18). Correction was

carried out in the following way: An osteotomy was performed at the site of the fracture in the left ramus of the mandible. This permitted the main portion of the lower jaw to be carried to the right and the chin to the midline position. Fixation by means of the teeth being impossible, a circumferential brass wire was passed around each fragment and the ends brought out through small skin incisions and attached to metal bars (coat hanger wire) coming down from a plaster of Paris head cap (Fig. 19). By this means the fragments were held in normal relationship. Fig. 20 is from a radiograph made at this time and shows the circumferential wires and also the gap created between the fragments after they were properly reduced by the osteotomy. After waiting for about six weeks for healing from this preliminary operation, the gap in the mandible was filled with a bone graft from the crest of the ilium (Fig. 21). Consolidation took place in eight weeks, the circumferential wires and headcap were removed, and the patient was then able to have full upper and lower artificial teeth made, with which he could masticate (Fig. 22).

CASE 6.—In this case is illustrated a unilateral defect of the mandible with retrusion of the chin. The patient in this case was an 18-year-old boy, who, when 8 years of age, had had a resection of several inches of the left side of the mandible for a tumor, reported to be a sarcoma. Later, two attempts were made in another city to restore the defect in the mandible by rib grafts, which were unsuccessful. Examination showed the typical deformity resulting from a defect of one side of the mandible. There was marked shortening on the left side, causing the large segment of the lower jaw, with its teeth, to be drawn over toward the left, attached by fibrous tissue to a short left segment consisting of the ascending ramus and the coronoid and condyloid processes. There were no teeth on the left side beyond the first incisor, and the remaining mandibular teeth had no relationship with the upper teeth, being drawn backward and inward. He could open his mouth widely, but there was a marked deviation of the lower jaw to the left (Fig. 23). The profile showed marked recession of the chin. There was a dense external scar adherent to the bone on the left side (Figs. 24 and 25). Fig. 26 is from a radiograph showing preoperative condition of the bone on left. Correction of this case involved several steps:

1. Division of fibrous adhesions between the ends of the mandibular fragments and remains of the rib graft on the left side to allow the main portion of the lower jaw and teeth to be carried to the right and forward into more normal position. After the adhesions had been severed it was possible to bring the lower teeth into fairly good occlusion with the upper and hold them there by means of arch wires. This interdental fixation was supplemented by a circumferential wire around the symphysis, forward traction on the chin being maintained by attachment of the wire passing around the bone to a bar coming down in front of the face from a plaster of Paris headcap. This forward traction was maintained for about three weeks, after which fixation was continued by the wires attached to the teeth.

Fig. 17 (Case 5).—Deviation of chin to left due to malunion of fracture of left ramus of mandible.

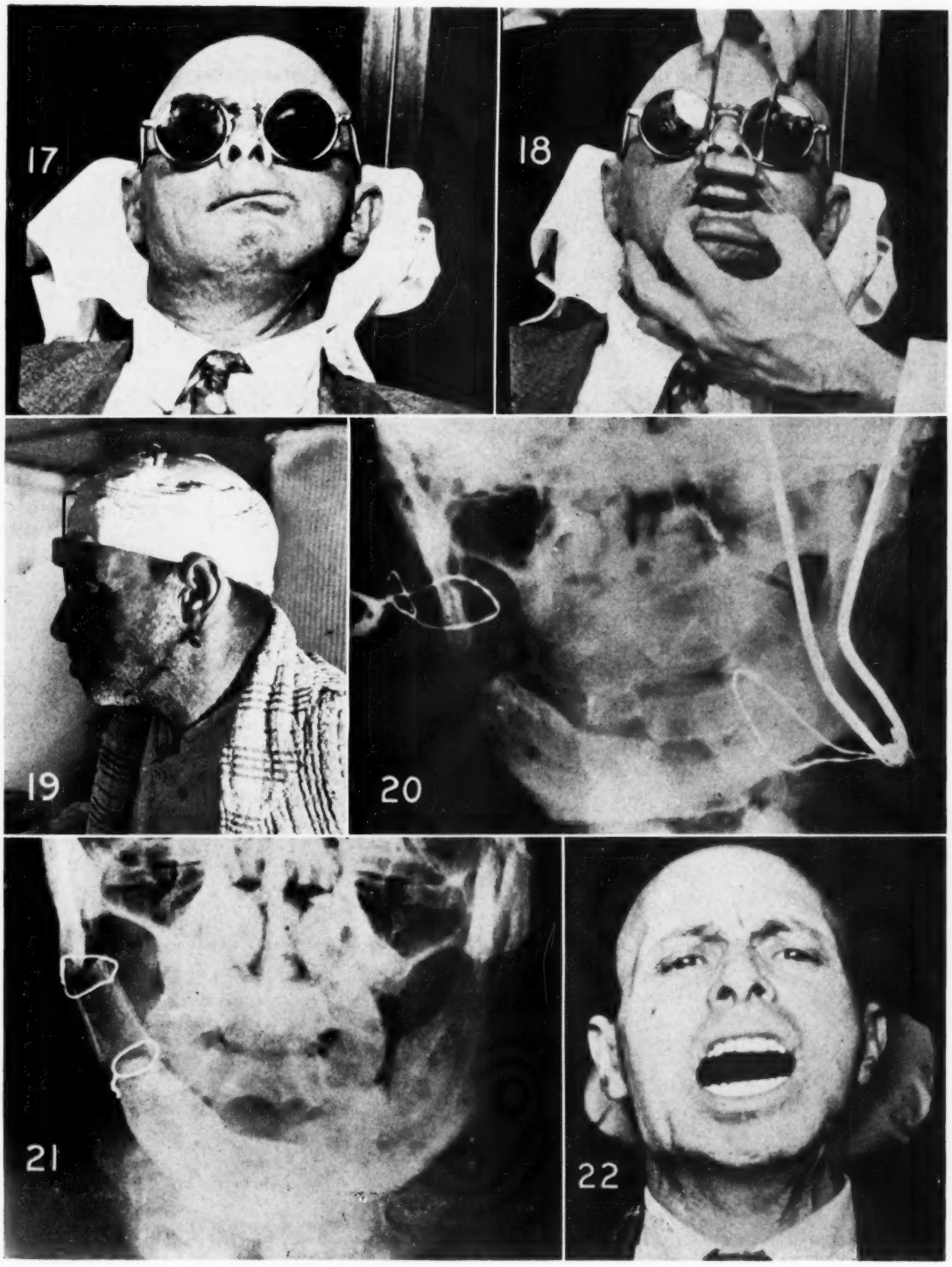
Fig. 18 (Case 5).—Restriction of opening of mouth and malrelationship of edentulous upper and lower alveolar arches rendering impossible insertion of artificial dentures.

Fig. 19 (Case 5).—Fixation of fragments after osteotomy by circumferential wires and plaster headcap.

Fig. 20 (Case 5).—Radiograph after osteotomy showing gap in bone on left side and circumferential wires.

Fig. 21 (Case 5).—Radiograph showing gap in mandible filled with graft from crest of ilium, bringing about stabilization and restoration of length.

Fig. 22 (Case 5).—After restoration of correct position of jaw and increase in mouth opening, permitting insertion of artificial dentures.



Figs. 17-22. *(For legends see opposite page.)*

2. Replacement of the dense scar over the operative field by good skin and subcutaneous tissue. This was accomplished by transplantation of a tube pedicle flap from the left clavicular area.

3. Restoration of the length and continuity of the left side of the mandible by a bone graft. Three months after the first operation, the wounds from these preliminary operations having healed, a graft two and one-half inches in length and

Fig. 23 (Case 6).—Marked deviation of lower jaw to left on opening mouth due to loss of bone on left side.

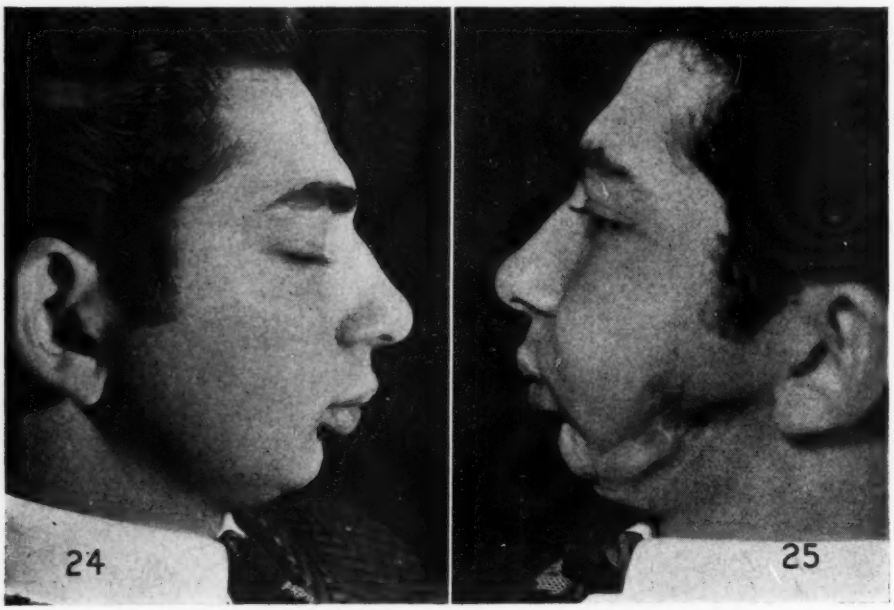


Fig. 24 (Case 6).—Right profile before treatment showing backward position of chin.

Fig. 25 (Case 6).—Left profile before treatment showing adherent scar.

comprising the entire width of the crest of the left ilium, was removed with a metacarpal saw, and after exposure of the ends of the separated mandibular fragments, it was inserted in the gap, being fastened to each fragment by brass wire sutures passed through holes drilled in the bone (Fig. 27). This operation was followed by some low-grade suppuration, which stopped after removal of one of the suture wires two months later. Shortly after this, the wire fixation on the teeth was discontinued, and union of the graft with stabilization of the jaw was found to be complete.

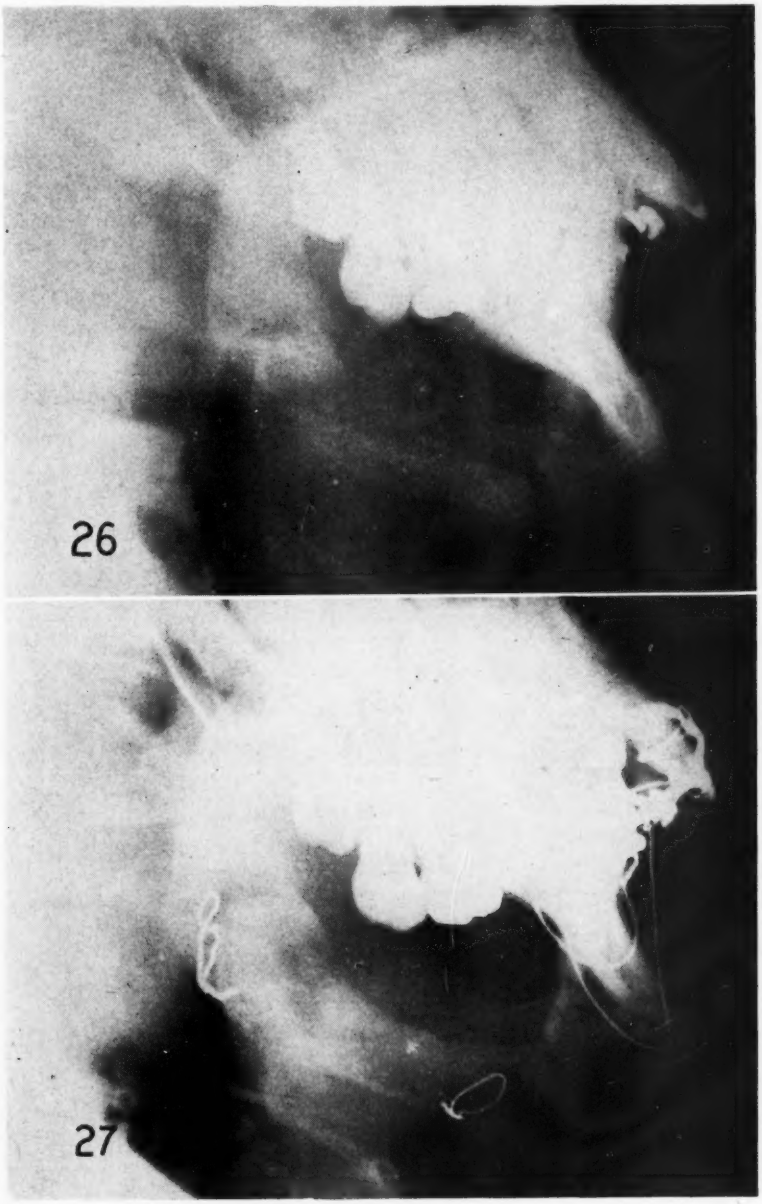
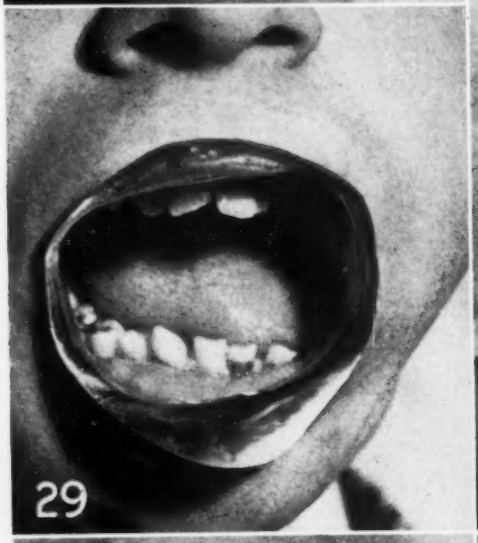
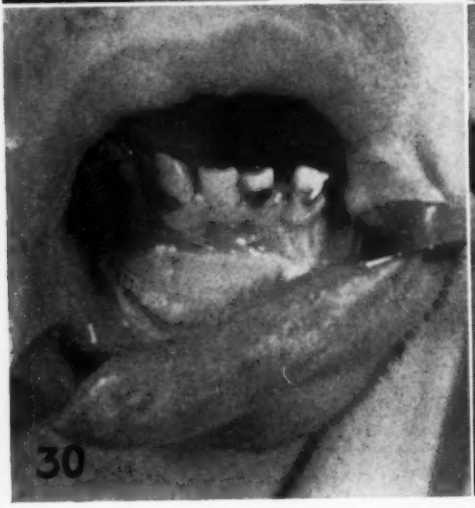
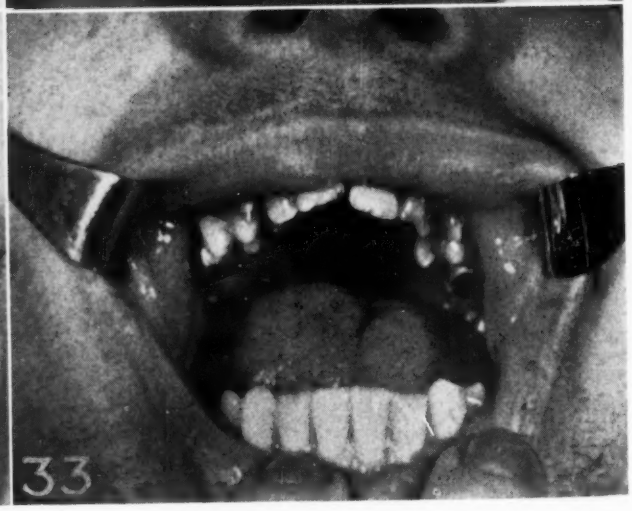


Fig. 26 (Case 6).—Radiograph showing defect in left side of mandible and remains of unsuccessful rib graft.

Fig. 27 (Case 6).—Radiograph showing restoration of continuity and length of left side of mandible by graph from crest of ilium.







Figs. 28-33. *(For legends see opposite page.)*

Figs. 28 and 29 show the occlusion of the teeth at that time and also the mouth opening, with better central position of the mandible.

4. Additional prominence to the chin and restoration of occlusion by provision of artificial lower anterior teeth. Four months after the bone-grafting operation, the mucous membrane in the vestibule of the mouth beneath the anterior mandibular teeth was divided by an incision extending from one premolar region to the other, and the soft tissues were separated from the periosteum over the anterior surface of the mandible almost down to its lower border. This created a deep pocket in the soft tissues behind the lip, which was then lined with a split-skin graft supported on a mold of dental impression compound. This was held in position for several days by circumferential sutures. After removal of the compound, the pocket was found to be lined with skin (Fig. 30). The patient then had a partial denture* constructed

Fig. 34 (Case 6).—Improved profile after completion of treatment. Compare with Fig. 24.

of acrylic material, which fitted over the natural lower anterior teeth and which occluded well with the upper teeth. An extension from the appliance passed down into the skin-lined pocket to build out the chin to a considerable extent. The patient's jaw is now stable, with normal opening and closing, and with the appliance in place he is able to masticate any kind of food; also, the profile is greatly improved (Figs. 31, 32, 33, and 34).

CASE 7.—In this case is illustrated a defect of the cheek and palate resulting from radiation treatment for carcinoma of the upper jaw. A female, single, aged 25, had been first treated three years previously by x-rays and radium for a lesion of the upper right jaw, diagnosed as carcinoma of the right maxillary sinus, verified by biopsy. As a result of the treatment, the soft tissues of the cheek sloughed, ex-

*Dr. Frank A. Fox, University of Pennsylvania Dental School, constructed the denture.

Fig. 28 (Case 6).—Improvement in occlusion of teeth after bone graft.

Fig. 29 (Case 6).—Disappearance of deviation of mandible to left on opening mouth after stabilization of jaw by bone graft. Compare with Fig. 23.

Fig. 30 (Case 6).—Pocket between bone and soft tissues of chin lined with split-skin graft.

Fig. 31 (Case 6).—Artificial appliance to supply missing teeth and build out prominence of chin (Courtesy of Dr. Frank A. Fox).

Fig. 32 (Case 6).—Artificial appliance in place, mouth closed, showing good occlusion of teeth.

Fig. 33 (Case 6).—Artificial appliance in place, mouth open.

posing the necrotic malar and maxillary bones on the right side (Fig. 35). No evidence of the original malignancy remained, but the surrounding skin showed marked atrophic changes. At the first operation a large sequestrum was removed, comprising most of the right malar and maxilla including the palatal and alveolar processes, and the teeth attached to it, as well as the septum of the nose. This left a large opening in the right cheek, into the maxillary sinus and nose, and a defect comprising the entire right side of the hard palate. This caused marked impairment of speech. At the time the dead bone was removed, a long tube pedicle was prepared from the right anterior axillary fold down to the groin to be used later to repair

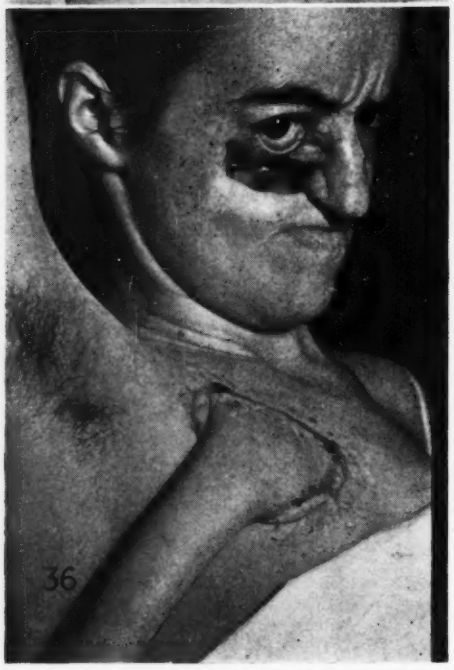


Fig. 35 (Case 7.)—Extensive radiation necrosis of right malar and maxilla with destruction of soft tissues of cheek.

Fig. 36 (Case 7).—Opening through right cheek into maxillary sinus and nose after removal of dead bone. Tube pedicle flap from axilla to upper part of chest, to be used later for repair of openings in face and mouth.

the face. Fig. 36 shows an intermediate transfer of the tube pedicle to the upper part of the chest and the defect in the cheek. After the first operation it became necessary to wait several months before attempting repair of the facial defect, until all infection had cleared up and remaining dead bone had come away. Pathologic examination of tissue removed from the edges of the defect and from the cavity from time to time showed no persistence of the malignancy. Eight months after the first operation, the distal end of the flap was severed from the axillary region and, after freshening the edges of the opening in the cheek, the end of the tube was flattened out by excision of intervening fat to create two surfaces of skin, one being sutured to the edges of the defect facing in to replace the linine of the maxillary

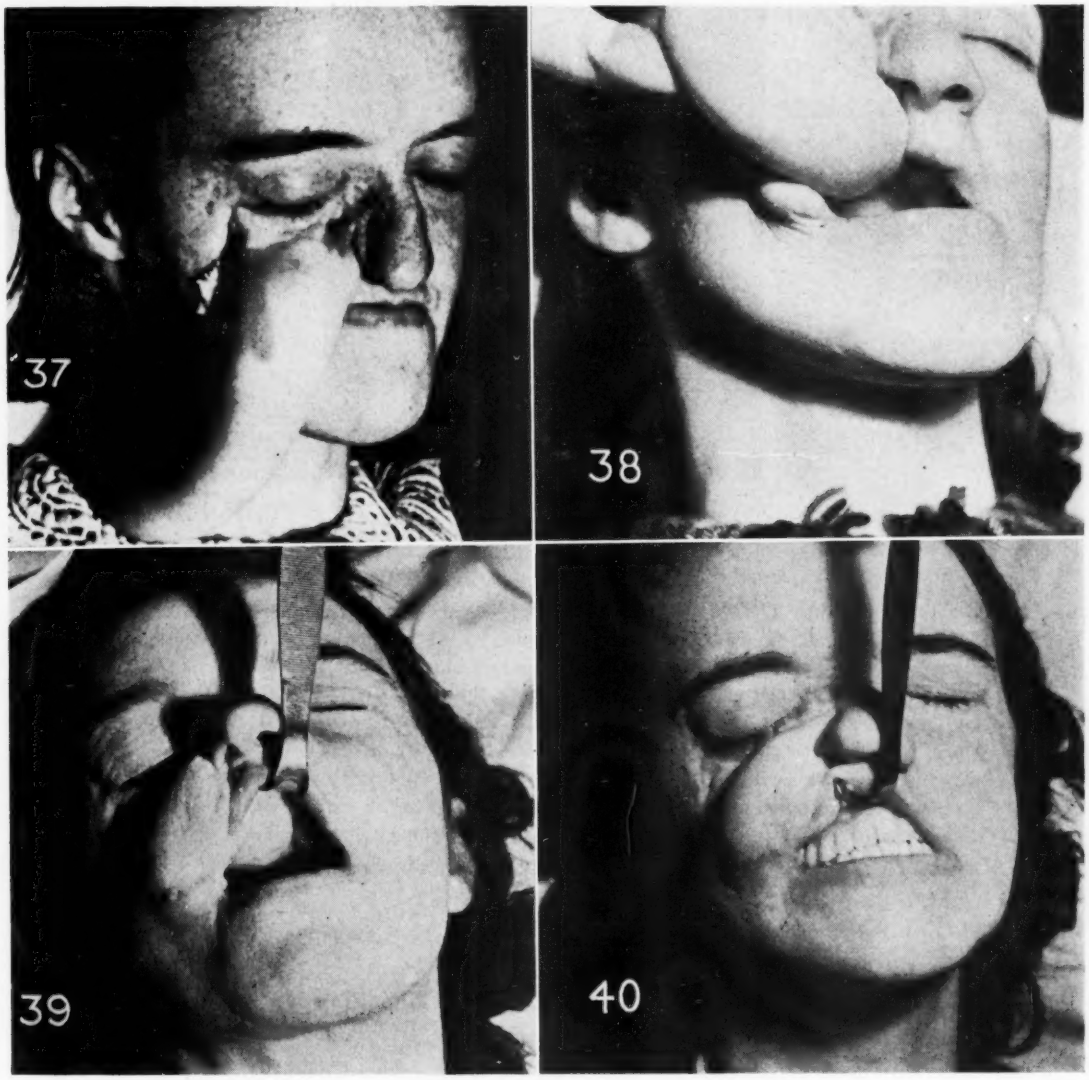


Fig. 37 (Case 7).—End of tube pedicle from chest sutured to cover opening in cheek.

Fig. 38 (Case 7).—Other end of tube pedicle sutured to edges of defect in hard palate.

Fig. 39 (Case 7).—Defect in hard palate completely closed by skin flap.

Fig. 40 (Case 7).—Artificial teeth inserted.

sinus and the other facing out to replace the lost external skin (Fig. 37). Considerable difficulty was experienced in getting the skin of the flap to heal well to the poorly nourished skin surrounding the defect. Four months elapsed, therefore, before it was considered safe to proceed with the next stage. Then, the flap was cut loose from the chest and the free end was in turn thinned out to form two skin surfaces, which were then sutured into the palatal defect, forming upper and lower layers. In order to introduce the end of the flap into the mouth it was necessary

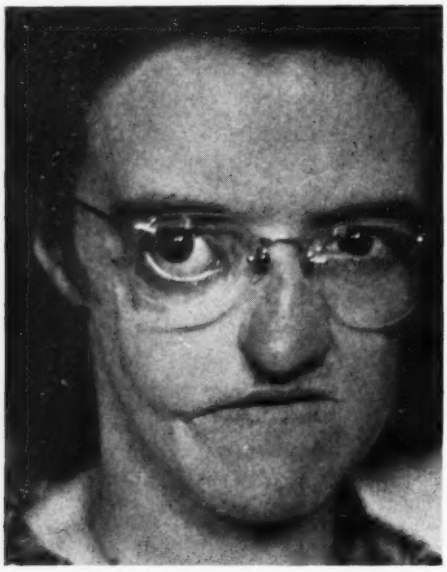


Fig. 41 (Case 7).—Present external appearance, subject to further improvement by thinning out of flap, smoothing of edges, etc.

to divide the right side of the upper lip, and this was later repaired. Fig. 38 shows the tube, forming a loop, with one end on the cheek and the other in the palate. After a few weeks it was noted that the opening in the palate had been completely closed by the skin flap. The loop was then divided where it emerged from the mouth. The freshened ends were trimmed to fit the remaining free edges of the cheek and mouth defects, respectively, and sutured in place. Later, several minor operations were done to thin out and shape the cheek flap, and a piece of costal cartilage was inserted beneath the lower eyelid to support the right eyeball. An upper artificial denture* was made, enabling the patient to masticate food with satisfaction. The marked defect in speech was immediately overcome by operative repair of the palate, and her appearance was greatly improved (Figs. 39, 40, and 41).

*See footnote on page 71.

EVALUATION OF PEDICLE FLAPS VERSUS SKIN GRAFTS IN RECONSTRUCTION OF SURFACE DEFECTS AND SCAR CONTRACTURES OF THE CHIN, CHEEKS, AND NECK

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THE treatment of skin defects constitutes an important phase in plastic surgery. In this paper communication we are mostly concerned with the treatment of extensive surface defects and disfigurements of the chin, cheeks, and neck. Injuries caused by fire of clothing around the neck are quite common on children, especially of poorer families where supervision of the playing child is often neglected. Another common injury in this locality is the x-ray burn, resulting from excessive x-ray treatment formerly given in cases of hypertrichosis. Injuries caused by acid are quite similar to those caused by fire. Undoubtedly the great variety of war casualties also produce many surface injuries in this region.

In general, it can be stated that regardless of the cause, the principles of reconstruction are very much the same. The issue of first importance in granulating wounds after extensive injuries is the quick epithelization. The cosmetic effect is rather of secondary importance. Undoubtedly the most advantageous treatment is early skin grafting.

The treatment of patients with old scars and scar contractures presents an entirely different problem from those with fresh injuries and defects. Extensive burn scars of the face where the scar is superficial, soft, and smooth, offers a real dilemma to the surgeon. I have in mind scars caused by second degree burns where only the superficial layers of the epidermis are destroyed. One must realize that the transplanted skin also has its esthetic shortcomings and is far from being a perfect match to the normal skin. Therefore, in mild cases of scarring, it is of paramount importance to know our limitations and advise against operation.

If one or two contracting, scarry bands are present, shifting of the skin with a Z plastic is sufficient in suitable cases.

In mild cases of x-ray burn where no breaking down of tissues or ulceration is present and there is only the typical atrophy and discoloration of the skin, it is safer to discourage transplantation. A heavy, colored, make-up cream will give more satisfaction. There is time for surgical intervention if and when the breaking down of the atrophied skin takes place.

Extensive defects of the chin, cheeks, and neck, heavy hypertrophic scars causing distortion and functional disturbance, and crippling contractures are cases where plastic surgery can offer real relief.

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Severe x-ray or radium burns with ulceration, considerable pain, and danger of malignant changes are also cases in which conservative treatment must cease in favor of radical surgery.

Considering the favorable experience with *tubed* flaps in comparison with *open* flaps, there is seldom an occasion for the use of open flaps. Where large surfaces of skin need to be transplanted, the advantages of the tubed flap, or "skin tubes," are: (1) the protection of the wound surfaces from exposure to infection; (2) the small amount of fibrous tissue formation, therefore its pliability; and (3) the easy stages and long intervals between operations.

The skin tube can be moved repeatedly: therefore it can be taken from a site distant from the defect if necessary; or it can be attached to an intermediary host, such as the hand (Fig. 4, *H*).

Skin tubes can be formed on practically any part of the body. For the repair of extensive defects, the most advantageous sites are: (a) axilloabdominal; and (b) transverse or oblique abdominal (transferred usually via hand). In case of necessity, (c) acromiopectoral, and (d) dorsal tubes can also be used.

Very long tubes can be prepared, with proper caution, due to its well-protected blood supply. It is possible to make a tube so long that the skin of the lower abdomen can reach the face in one shift (Fig. 1, *G* and *J*).

In selecting the donor site, the following points must be considered:

1. The skin of the donor area should be a good esthetic match with the locality of the defect in color, texture, and thickness.

2. An adequate amount of skin should be obtainable.

3. It should be relatively convenient to transfer from the donor area to the defect.

4. The secondary scar of the donor area should be hidden, and should not cause functional disturbance.

Careful analysis should be made of the size and contour of the defect. The inexperienced surgeon often tends not to provide large enough flaps. To overcome this, he tries to suture under tension which leads to necrosis.

The following points relative to the technique of forming the tubed flap are important:

1. Strict surgical asepsis.

2. Thorough hemostasis within the tube to avoid hematoma.

3. The length of the flap should not exceed three times its width, preferably two and one-half times. If longer tubes are necessary, they should be prepared either in sections with intermediary pedicles (Fig. 1,

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Fig. 1.—*A*, *B*, and *C*, Preoperative photographs of patient with burn scars of chin and lower lip caused by fire of clothing. *D*, *E*, and *F*, Postoperative photographs after reconstruction of chin and lower lip with axilloabdominal skin tube. *G*, Axilloabdominal skin tube. *H* and *I*, Showing attachment of temporary intermediary pedicle of axilloabdominal skin tube. *J*, Axilloabdominal skin tube attached to face.

Fig. 1. (*For legend see opposite page.*)

H and *I*), or in different operative stages. The intermediary pedicle can be detached in seven to ten days. If there are more, only one should be detached at a time.

4. The tube should preferably be formed in the direction of the blood supply.

5. On thin persons, the skin flap should include the entire fat layer, down to the fascia. Thus, the blood supply is less interfered with.

6. On obese individuals, enough fat should be left on the skin flap so that when it is closed the tube should be filled without causing abnormal pressure. A too flabby, empty tube is not satisfactory because it might shrink and be difficult to stretch the skin to the original size.

7. Thinning out too much of the subcutaneous fat layer might interfere with the blood supply.

8. During healing, the tube should be carefully guarded against stretching, twisting, or pressure.

9. The longer the tube, the slower its transfer should be. Delaying operations (detaching and resuturing part or whole of the end to be transferred) will enhance the blood supply.

10. A tube made of a flap of basic proportions, one width by three lengths, can be moved in about three or four weeks. With the increase in length, the transfer should be deferred according to the condition of the tube. Caution should be observed when the tube is hard and edematous.

11. Where the flap covers penetrating defects it should be lined with a skin graft or skin flap before being transferred.

Occasionally it happens that the end of the skin tube necrotizes (Fig. 2, *H*). Ordinarily this is due to some technical shortcoming such as too early transfer, suturing under tension, twisting, pressure, or stretching of the tube, or infection. Owing to the fact that the tubed pedicle is most of the time longer than is needed for the defect, it can be easily corrected (Fig. 2, *I*). If a partial necrosis occurs in the mid-portion of the tube, it can be patched with a flap from the neighboring skin.

In reference to good cosmetic results with skin tubes, the following points should be observed:

1. The size of the defect should be carefully considered. There is always a danger of not having enough material. Length of the skin cannot be stretched into width with good cosmetic effect. One should provide wide enough flaps in the beginning.

Fig. 2.—*A*, *B*, and *C*, Preoperative photographs of patient with burn scars of chin, lower and upper lip, and left ala nasi, caused by fire of clothing. Left eye was also lost. There had been previous corrections on the chin with skin grafts; there was a recurring abscess formation from an epidermoid implantation cyst. *D*, *E*, and *F*, Postoperative photographs after reconstruction of chin with thoraco-abdominal skin tube. Left side of upper lip was reconstructed with postauricular skin graft, left ala nasi reconstructed with free skin-cartilage graft from ear. *G*, Thoraco-abdominal skin tube. (Lengthened in subsequent operations before transfer.) *H*, Partial necrosis of end of skin tube. *I*, Skin tube re-attached after necrotic part cleared.

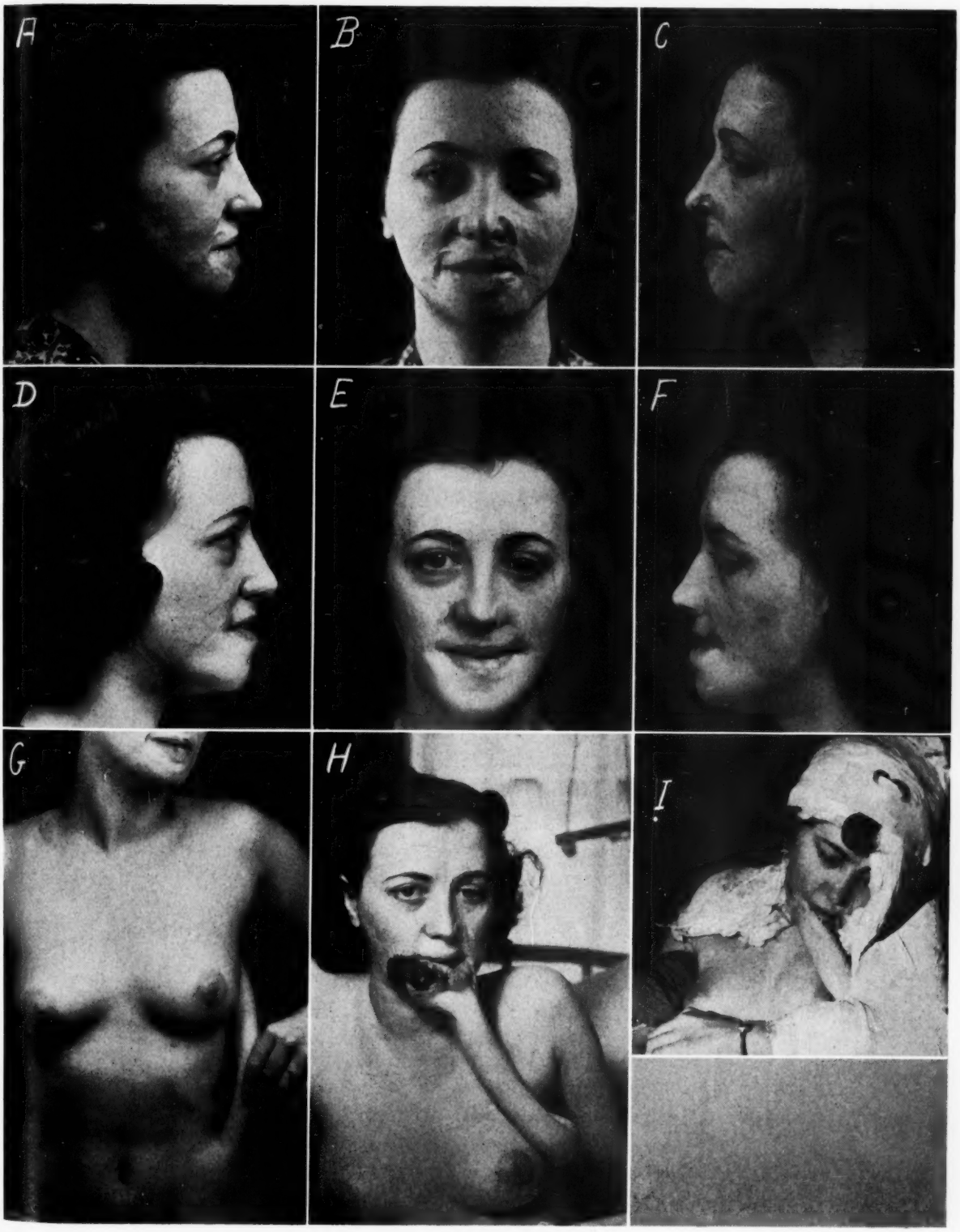

Fig. 2. *(For legend see opposite page.)*

2. Large transplants have a better cosmetic effect than small ones.

3. No old scar should be spared between transplanted and healthy skin.

4. The replacement should cover esthetic units. For instance, if a scar almost reaches the nasolabial fold, the transplant should extend to the nasolabial fold.

5. In extensive reconstruction of the chin, the flap should extend to the vermilion border, even if healthy skin has to be sacrificed. Small islands of healthy skin in this region only spoil the esthetic effect and do not help functionally.

6. With scars extending to both sides of the face, the replacement should be symmetrical even if healthy skin has to be removed.

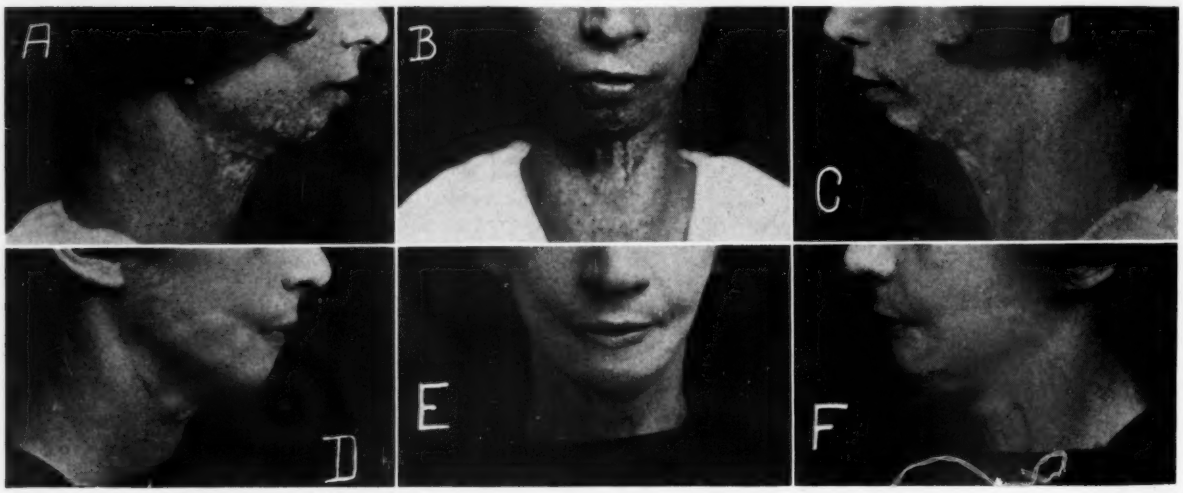

Fig. 3 *A-F.—A, B,* and *C,* Preoperative photographs of patient burned by fire. Hypertrophic scars were treated with x-ray. Several years later x-ray atrophy and persisting ulceration appeared on the chin. There had been previous operations with skin graft. *D, E,* and *F,* Postoperative photographs after reconstruction of chin and neck with acromiopectoral skin tube.

7. To cover the entire chin and cheeks from ear to ear with one piece of skin is difficult. The scar of division should be carefully planned in an esthetically inconspicuous place (Fig. 4, *E*).

8. The suturing of the flap to the bordering skin should be meticulous in order to leave fine scars.

9. The flap should be tacked down with catgut sutures to the undersurface, to prevent dislocation and hematoma formation.

10. The flap can be thinned and modeled step by step after the transfer has been completed.

11. At the angles of the mouth, small portions of healthy skin should be spared for better function.

Where well-padded, large surfaces of skin are necessary and the best possible cosmetic effect is essential, the tubed flap offers better results than free grafts. However, working with tubed flaps has its disadvantages, too.

The greatest drawback is the time element and the repeated operations involved in its transfer. The minimum number necessary for the transfer of a medium-sized skin tube, about three by eight inches, from the donor area to the defect is three stages: (1) forming the tube; (2) moving one end to the defect; and (3) spreading the skin over the defect. The shortest time interval between each operation is three weeks. This means that for the transfer of a medium-sized skin tube, at least two months are necessary.

If the skin tube has to be advanced from a greater distance by caterpillar movements, or via an intermediary host, one or two more operative steps are necessary with adequate time intervals.

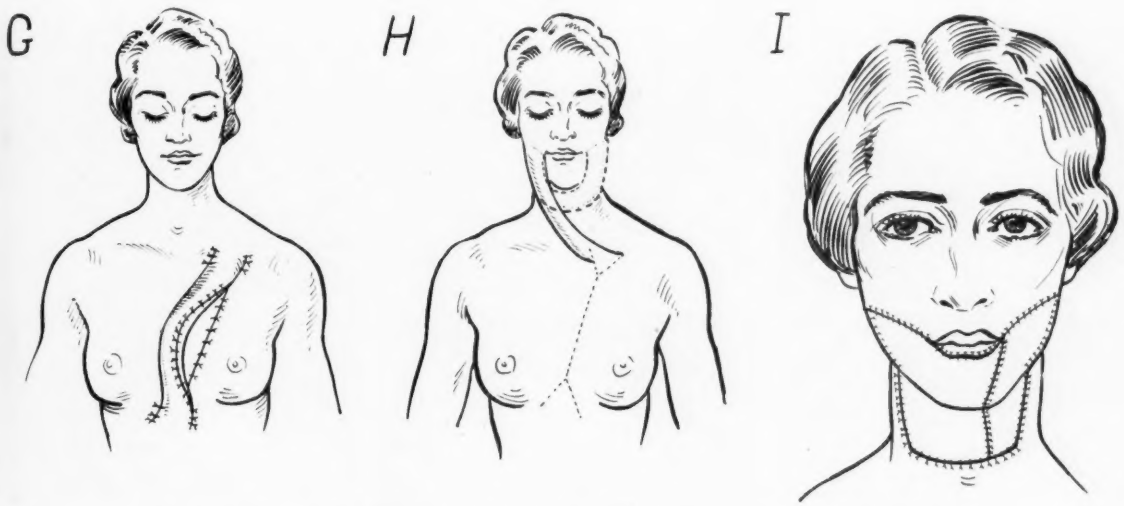

Fig. 3 *G, H,* and *I.*—Diagrams of reconstruction with acromiopectoral skin tube.

With large skin tubes, naturally more time must be allowed between stages. In Case 4, where six by eighteen inches of skin, that is, over 100 square inches, was transferred from the abdomen to the face, it required seven operations to complete the transplantation and took about seven and one-half months. Naturally, the patient did not have to be hospitalized during the entire time. Only one or two weeks hospital stay with each operation was sufficient.

With the application of free skin grafts instead of tubed pedicle flaps on contractures of the chin and neck, the time of reconstruction can be reduced considerably. Instead of from four to six months which are required for tubed pedicles, only two or three weeks are needed for free grafts.

Skin graft for the treatment of contractures of the chin and neck has been advocated by different surgeons. With the improvement in technique and safe healing, more and more are following this method.

A great impetus in the use of skin grafts has been the ingenious invention of Earl Padgett of Kansas City, the Dermatome. With this mechanical device, large skin sheets of predetermined, calibrated thickness can be cut with relative ease. This invention radically changes the indication and application of skin grafts.

Fig. 4 *A-F.*—*A*, *B*, and *C*, Preoperative photographs of patient with burn scar contracture of chin, cheeks, and neck caused by fire of clothing. *D*, *E*, and *F*. Postoperative photographs after reconstruction with abdominal skin tube.

The tremendous time saving with grafts versus tubed flaps is not the only advantage. One cannot overlook the surgical risk and discomfort involved in five or six operations. Beside this, the patient is handicapped physically during all these operations and treatments. Finally, the economic aspect, due to prolonged disability and frequent hospitalization, is one of the most important factors which may decide against tubed flaps.

In spite of these disadvantages, we cannot afford to abandon work with tubed flaps. In cases where the best possible esthetic result is important, and the elements of economy and time are secondary, tubed flaps are still superior. They are safer in regard to "full take." With careful observation of the previously mentioned technical points, large surfaces of skin can be transplanted with relative safety. On the other hand, with skin grafts there is more of a risk of partial necrosis.

The well-padded flap does not shrink after healing. On the other hand, the skin graft, whether thick or thin, always shrinks due to the

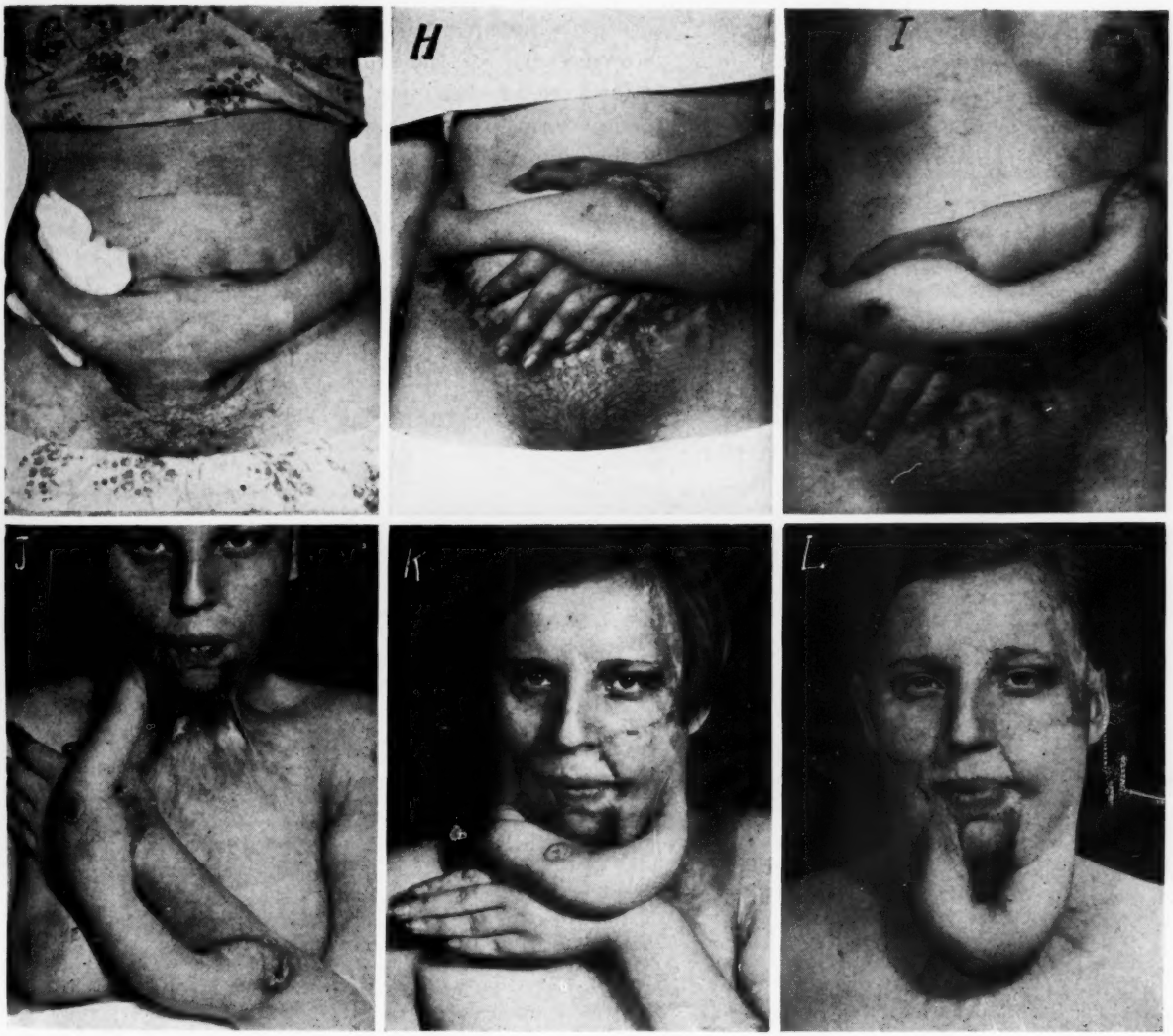

Fig. 4 *G-L.*—*G*, Abdominal skin tube, six by eighteen inches long; central portion still attached. *H*, Central portion of abdominal skin tube attached to back of hand. *I*, Left end of skin tube attached to forearm. Dark spot in center of tube is superficial burn caused by hot negocoll when moulage was prepared. *J*, Skin tube transferred via hand to face. *K*, Both ends of skin tube attached to face. Central portion still attached to hand. *L*, Skin tube entirely free of intermediary host and nourished by facial attachment. Subsequent operation, skin tube cut and spread over defect. Notice vertical scar on left side of chin in *E* where flaps were joined.

scar layer being in direct contact with the corium. Naturally, thicker grafts will better withstand this shrinking effect than the Thiersch graft. In extreme cases, the shrinking of the connective tissue layer manifests itself on the surface in waviness and folds.

If a supporting frame, bone, or cartilage has to be reconstructed under transplanted skin, it is unquestionably easier to do it under thick, fat-padded flaps than under skin grafts, if that is possible at all. Furthermore, the flaps are more suitable for surgical modeling, revisions, and shifting.

All these points brought out in comparing the skin grafts with the pedunculated flaps prove that both methods have their advantages and disadvantages. We cannot discard either of the methods or put one ahead of the other with a sweeping general statement. The best service can be given to the patient if the advantages and disadvantages are carefully weighed in each case and the choice of method made accordingly.

THE VASCULAR PREREQUISITES OF SUCCESSFUL SKIN GRAFTING

A New Method for the Immediate Determination of the Adequacy of Circulation in Ulcers, Skin Grafts, and Flaps*

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(From the Department of Medicine, New York Medical College, Flower and Fifth Avenue Hospitals and Metropolitan Hospital Research Unit)

VASCULARITY of tissues is of prime importance in wound healing and repair of tissue damage. Avascular tissues depend on lymph spaces for interchange of nutritive and waste materials. Such tissue may possibly survive but it is not capable of repair and reconstruction. Infection is much more apt to occur in tissue with insufficient vascularity and an infection, once present, can only be overcome by the organism if the reparative mechanism is fully intact, that is providing there is a full rapidly circulating blood supply present.

All types of plastic surgery are, therefore, profoundly dependent upon the presence of an intact vascular apparatus in the field of operation. The recent trend to graft large wounds early, and to depend more on good vascularity than on absolute sterility takes these facts into consideration.

The question as to whether a large wound is well supplied with blood is often hard to decide. Again the extremes are easy to deal with. The freshly granulating pink surface of a clean surgical wound can generally be depended upon to have full vascularization. The gray dirty-looking surface of an old infected ulcer will easily be recognized as having insufficient capillarization. However, the more one carries out the test to be described, the more one will be astonished to see how often, even in a fresh looking ulcer, there are large islands of poor vascularity, and that these islands must not necessarily show a color deviating from the surrounding tissue. Since a successful take in skin grafting depends largely upon the adequacy of circulation in the wound on which the graft is to be put, the immediate recognition of the vascularity must be considered highly important.

In pedunculated flaps it is important to be able to decide at once whether the flap which is created by the surgeon is fully supplied with blood through its pedicle, so that it can survive until its successful connection to the vascular apparatus of the wound on which it is being grafted. Before the separation of the flap from its pedicle one must be

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sure, especially in tubular flaps, that the vascular connection between the graft and its bed has been established in order to avoid sloughing.

Some time ago Lange and Boyd[1] were able to show that fluorescein when injected in a 5 per cent alkaline solution intravenously, travels with the blood stream, reaches the capillaries, and diffuses into the tissue wherever the blood stream reaches an area. This test, which we first devised for the immediate diagnosis of viability of gut in cases of strangulated hernia,[1, 2] can also be used in plastic surgery. The fluorescein can be seen directly in the capillaries and the tissue cells when observed under long wave ultraviolet light. It is, therefore, obvious that this method may be able to aid in establishing the adequacy of circulation in areas where skin grafting is contemplated and also in flaps before and after the grafting.

METHOD

In a moderately, or better, fully darkened room the beam of a special small portable and inexpensive mercury vapor lamp* is directed by an assistant on the area under observation. This lamp carries on its surface a glass filter which excludes all of the harmful ultraviolet and most of the visible light. It transmits light mainly in the region of 3,600 angstrom units. The ulcer or the skin flap will thus appear dark purple or slightly bluish green. For the purpose of later comparison it is advantageous to compare this color with that of the skin of one of the assistants under this light. The patient now receives an intravenous injection of 10 c.c. of a 5 per cent fluorescein solution to which 5 per cent sodium bicarbonate has been added to make it soluble.† This dye is entirely nontoxic and is rapidly excreted into the urine. Within fifteen to twenty seconds, depending on the circulation time of the patient, the ulcer or the skin flap will acquire an intense golden green color in all districts which are reached by the rapid circulation. With the lapse of time the color becomes more intense since more of the dye diffuses from the capillaries into the tissue spaces. Only the living tissue is stained as we showed in other experiments. A clear contrast is created between the parts of the skin and the ulcer supplied with blood (they appear golden green) and the tissue not supplied (purple-blue). Since the light penetrates only 2 to 3 mm. into the tissue, the test gives an indication of the superficial blood supply and further scraping may reveal good vascularization in the depth as indicated by good fluorescence.[3]

EXPERIMENTAL EVIDENCE

Pedunculated flaps on the abdomen were formed in four rabbits. The area was clipped and depilated and, under nembutal anesthesia, the animals were operated upon under sterile conditions. In two animals the pedicle was purposely made very small as compared to the large

*Supplied by the G. W. Gates Co., Franklin Square, Long Island, N. Y.
†Supplied by the C. F. Kirk Company, New York.

flap. Then 0.4 c.c. of the fluorescein solution was injected into the ear vein and the area of the flap which showed fluorescence was outlined with a skin pencil. The flap was replaced on its previous bed and the course of the healing observed. Both animals showed necrosis of the skin flap within forty-eight hours after operation, exactly at the line of demarcation as previously indicated by the fluorescein.

In two animals the skin flap was formed according to the usual procedure, that is, the pedicle was not essentially smaller than the flap. Otherwise the procedure was the same as in the other animals. The fluorescein test indicated full fluorescence throughout except for the tip of one of the flaps which was cut off. Both animals showed a normal take of the flap without any gangrene.

Three rabbits were subjected to the same procedure and a pedunculated flap formed with the pedicle nearly the same width as the flap. In these animals the pedicle was prevented from taking, however, by putting a piece of rubber dam between it and the underlying tissue. The flap itself was sutured on its old bed after the fluorescein test had indicated full blood supply through the pedicle. Every forty-eight hours the animals were subjected to a fluorescein test with a tourniquet around the pedicle. Two animals showed the first traces of fluorescence in the flap after 144 hours when the blood supply from the pedicle was clamped off, while the third animal showed fluorescence after 192 hours. All pedicle transplants took completely. After eight, ten, and twelve days, respectively, full fluorescence of the entire flap was present with the pedicle clamped off, indicating full connection of the vascular systems of the flap and the base. It was interesting to note that the vascular connection always started at the edge and slowly progressed in irregular patterns toward the middle.

Davis grafts were removed from the flanks of two rabbits and from the hind legs of two others. They were transplanted on a fresh wound on the opposite side of the body. Some fluorescence indicating direct vascular connection was first discovered with great regularity after 96 hours and full fluorescence of the entire pinch graft was present in most of the grafts after 144 hours.

In this connection it should be mentioned, however, that in all animals the bed on which the flap or the Davis graft was implanted was fully vascularized and represented a fresh wound. All wounds showed excellent fluorescence throughout.

CLINICAL EVIDENCE

Since these examinations were started in the course of our observations of the effectiveness of the fluorescein test in peripheral vascular diseases and were not primarily intended as a surgical procedure, our clinical material is small as to actual skin grafting.

Seventy-six cases of leg ulcers were observed, and the value of the fluorescein test for their prognosis was tested. All patients received

9 to 10 c.c. of fluorescein slowly, intravenously. In nineteen cases the test was repeated at least twice to watch the progress of healing. It is very astonishing how clearly fluorescein shows where active circulation is present in ulcers, and how deceptive the simple visual observation of the color can be in borderline cases. It must be stressed, however, that the lack of fluorescence in an ulcer does not necessarily mean that the avascularity is a deep one. A thick layer of fibrin covering the vascular layer gives exactly the same impression.

Skin grafting on such a fibrin layer, however, can certainly not be considered ideal and may be the cause for subsequent slough. An ulcer, to be skin grafted, should be fluorescent throughout in the fluorescein test. In case it is not, the surface should be scraped until a layer of good fluorescence is reached.

Davis grafting on a leg ulcer was observed in one case and the implantation of the grafts was carried out only on areas where fluorescence was present. All grafts took and the first appearance of fluorescence under a cellophane dressing could be observed after ninety-six hours.

In one case of tubular grafting from the abdominal wall to the hand, the surgeons desired to know whether it was time to separate the flap on its new bed from its pedicle. A tourniquet was tightened around the pedicle and 10 c.c. of fluorescein were given intravenously. After eighteen seconds the entire tubular flap was well illuminated, especially in the vicinity of the sutures, indicating that it received a satisfactory blood supply from its new bed. A subsequent separation from its abdominal onset was fully successful.

SUMMARY

1. The vascularity and the active circulation in the capillaries of the wound as well as in vessels of a skin flap are most essential for successful skin grafting.

2. With the fluorescein test one is able to ascertain immediately the adequacy of the circulation in the skin flap as well as in the wound or ulcer.

3. In experimental animals (rabbits), it is shown that the fluorescein test exactly outlines the limits of active circulation in pedunculated flaps.

4. The first signs of direct capillary connection between the wound and the flap with the pedicle clamped were obtained after 144 hours.

5. Full vascularization of the flap from the wound was first present after eight days.

6. Davis grafts show the first signs of direct vascular connection after ninety-six hours.

7. The fluorescein test performed in seventy-six cases of leg ulcers of various origin proves that the mere observation of these ulcers in re-

gard to their appearance in daylight often gives a misleading impression of their vascular status.

8. Davis grafts in human beings also show the first signs of direct capillary connection after ninety-six hours.

9. Tubular grafts in human beings can easily be tested with the fluorescein method to determine the time when they can be separated from their pedicle without danger of sloughing.

I wish to thank Dr. Louis R. Kaufmann and Dr. John O. Herrlin for letting me examine several cases from their service.

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FIBRIN FIXATION OF SKIN TRANSPLANTS*

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THERE is good reason to believe that the artificial introduction of fibrin into certain wounds may help give local mechanical support to the tissues, and may at the same time promote rapid healing. Early in normal healing, newly forming connective tissues and blood vessels utilize fibrin as a scaffold upon which to build and, perhaps also, as a source of nutriment for the proliferating cells. Thus, the artificially supplied fibrin might be expected to aid the healing process, particularly in wounds in which little or no fibrin could be expected to form by natural exudation.

Some experimental work with the principle of fibrin fixation has been done in connection with nerve suture[1, 2, 3] and the results have been encouraging. To obtain the fibrin clot, citrated or heparinized plasma was clotted in the wound by the addition of calcium or of thromboplastin. The fibrin clot obtained sufficed to hold the severed nerves in apposition during healing. This technique for clotting the plasma in the operative field, however, is rather time-consuming and the tissues must be held in place until the clot forms about them; also, the plasma tends to drain away before clotting occurs.

In the present report we wish to summarize clinical studies on fibrin fixation of skin transplants. In operative procedures of this type, requiring placement of numerous individual structures, any delay in obtaining the fibrin clot would be particularly troublesome. We have obviated any such delay by using active thrombin to effect rapid clotting of the plasma in the operative field.

METHODS AND MATERIALS

The thrombin, prepared according to methods[4, 5, 6] developed in our laboratory during the past few years, is a highly active and relatively stable product obtained from beef plasma. Recently, one of the biologic firms† has developed facilities for producing the product in quantity for clinical use as a hemostatic agent, and thrombin obtained from this source was used in the present study. This preparation, "Thrombin Topical," was obtained in the form of sterile lyophilized powder in small vials, each containing 75 mg. of the material having 10,000 units of thrombic activity. (The thrombin unit is defined[4] as that amount which will clot 1.0 c.c. of standard fibrinogen solution in fifteen seconds.) The vial is sterilized immediately before use by immersion in antiseptic solu-

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†Parke, Davis & Co.
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tion. It is then rinsed with sterile water or saline solution to prevent contamination of the contents with germicidal solution when the vial is opened. The thrombin powder can be used in the dry form, but it is generally more convenient to dissolve the contents of one vial in 10 c.c. of sterile water or saline solution. This gives a solution having a strength of 1,000 units per 1.0 c.c. Thrombin solution of this concentration will clot ten times its volume of human blood in three seconds, and has been found to be highly effective as a hemostatic agent.[7]

Donor skin, to be transplanted, was first saturated with human plasma by immersion of the tissue in a container of plasma. Fresh homologous or autologous citrated plasma was used in a few instances but stored citrated plasma from the hospital blood bank was found equally satisfactory and was used in a majority of the cases. The recipient bed was flooded with thrombin solution immediately before the graft was placed. By this technique, the fibrinogen in the plasma with which the graft is saturated clots almost instantly and fixation of the graft in the clot is accomplished within a few seconds. It was found important that the grafts not be moved after being once placed; otherwise, the clot would be broken up, and fixation of the graft less satisfactory.

RESULTS

We have used fibrin fixation of skin transplants in 122 separate operations performed on a total of 53 patients. For simplicity of presentation, the cases have been divided into three main categories: (1) primary grafting procedures in which clean operative wounds have been grafted immediately, (2) burns, and (3) other types of chronically infected granulating wounds.

We have had nine cases of the primary graft type. In eight of these, split-thickness grafts, obtained with the Padgett Dermatome,[8] were used, and in the ninth a full-thickness graft was used. In these nine cases, defects ranging from 4 to 32 square inches in area have been covered with large sheet grafts. Fixation of the grafts in the fibrin clot was quite satisfactory and has reduced considerably the number of sutures which have been needed to hold the grafts in place. The final result of over 90 per cent successful takes was very gratifying. However, excellent results were to be expected in these cases with the usual technique of simply suturing the transplants in place. For this reason, it is difficult to evaluate the usefulness of fibrin fixation in terms of the final result obtained in such cases. In several of the cases the hemostatic action of the thrombin applied to the recipient bed proved very helpful in checking hemorrhage from the recipient bed. In the opinion of the operator, the thrombin, thus not only serves as the clotting agent for the artificially supplied fibrinogen but also serves to minimize considerably the danger of hemorrhage underneath the grafts, both at the time of operation and during the early postoperative period.

The second group of cases consisted of seventy-seven grafting procedures in connection with the treatment of burns in sixteen different patients. In only four instances did we have an opportunity to carry out grafting procedures earlier than one month after the burn was sustained. The remainder of the patients had had chronic granulating wounds for periods ranging up to seventeen months prior to admission. Many of the patients were markedly debilitated and the granulation tissue was often badly scarred and of very poor quality. The granulating areas ranged in size from one-tenth to one-half of the total surface area in the different patients. In seven of the sixteen cases, 30 per cent or more of the skin surface was involved.

In sixty-six of the grafting procedures carried out in the burn cases, the grafts were of the split-thickness type. Occasional sheet grafts up to 32 square inches in area were used, but for the most part the grafts were cut into "postage stamp" pieces. The fibrin fixation technique used was of great immediate mechanical aid in holding the grafts in place during the operation and during the application of the dressings. As in the case of the primary grafts, the hemostatic action of the thrombin used as the clotting agent for the plasma proved valuable in preventing hemorrhage from the granulation tissue. This was particularly true in some of the cases in which it seemed advisable to cut away portions of the exuberant granulation tissue at the time of the grafting operation. The grafts were usually protected by a plain gauze screen or wax mesh gauze screen. The ability of the fibrin clot to hold the grafts firmly in place was quite gratifying in most of the cases. In fact, in a number of the cases the grafts were left entirely open and merely protected from trauma by a wire cradle. In these, the fibrin proved adequate for mechanical support of the grafts in cooperative patients. In several of the cases grafts placed in dependent positions have been held successfully with no support other than the fibrin clot. The artificially supplied fibrin clot has also proved very useful to fix the gauze screen to the wound. To accomplish this, we flood the screen with a small amount of plasma and thrombin after it is placed in the desired position over the wound. In cases treated in this way no celloidin or other material has been needed to hold the screen firmly in place. Subsequent autolysis of the fibrin clot with loosening of the grafts, or of the screen, has not been a troublesome feature except in a few of the more severely infected wounds. This was equally true of the cases in which treatment of the wounds with wet dressings was resumed within two to four hours after the operation. This, we feel, is very valuable in that it permits resumption of aggressive treatment of extensive infections early in the postoperative period. Also, the stability of the grafts permits greater activity on the part of the patient during this period.

The usual difficulties in evaluating the efficacy of clinical therapy in terms of final results were, of course, encountered. In the group here reported, the over-all percentage of successful takes was 78 per cent.

This is somewhat better than we have had in the past with cases of this type. Other factors, however, as more careful attention to dietary and general treatment, segregation and special nursing service, frequent saline baths, and the local use of the sulfonamide drugs, no doubt have contributed much to the improved results. For this reason, it is difficult to evaluate the influence of any single factor. There can be no doubt, however, but that the fibrin fixation has been at least of considerable mechanical aid. Conclusive data showing a stimulating effect on the healing process are not available, but this has been suggested by surprisingly good results in some of the more unfavorable cases.

In the remaining eleven grafting procedures in burn cases, the grafts were of the "pinch" type. In these, again, the use of thrombin and plasma for fixation of the grafts in a fibrin clot was of definite mechanical aid and the results suggested that the persence of the artificially supplied fibrin increased the likelihood of the grafts remaining viable. The percentage of successful takes in this group (73 per cent of all grafts survived) was not quite as good as in the case of the split-thickness grafts, but in general the pinch type grafts were elected in the less favorable cases.

There were thirty-five grafting procedures in cases which fell into the category of chronically infected wounds, other than burns. Most of these were cases in which the chronic granulating wounds followed surgical treatment of severe infections. In these, thirteen were of the split-thickness type and twenty-two of the pinch type. The results in these (68 per cent) were slightly less favorable than in the burn cases. The usefulness of the fibrin clot for mechanical support of the graft was more evident perhaps in this group because of the nature of some of the wounds. In several of the cases, deep crater defects required placing numerous small grafts on the sides and bottom of the crater. Many of these would have been very difficult to hold in place by any other means and the fibrin proved adequate to hold the grafts in place until healing occurred.

In this study, we have arbitrarily classified as successful, all transplants which appeared healthy on the tenth to the fourteenth postoperative days. In the case of small transplants, the percentage takes was determined by counting the total number of grafts. In the case of the relatively few large sheet grafts, we have estimated the area of the graft which remained viable. In the entire series, there were about 8 per cent of the grafts in which "late slough" occurred two to four weeks after operation. No grafts were lost in this manner in the cases in the primary graft category. The percentage of the grafts eventually lost in this way was about equal in the cases falling into the other two categories and is about the same as we have had in the past in cases of this type. Our evidence, to date, does not indicate that the presence of the artificially supplied fibrin either increases or protects against this complication.

We have not yet had the opportunity to study the possible usefulness of the fibrin fixation technique in other types of operations. A few preliminary studies have been made in dogs with fibrin fixation of experimental bone transplants. Autologous plasma was used in these as the source of the fibrinogen and the thrombin described previously was used as the clotting agent. In these preliminary studies, the artificially supplied fibrin has appeared to be particularly helpful in fixation of thin osteoperiosteal grafts. Healing has proceeded very satisfactorily with no suggestion that the thrombin and plasma used had untoward effects.

DISCUSSION

The possibility of local irritation of the tissues resulting from the fibrin, or from the foreign protein of the thrombin which is prepared from beef plasma, naturally arises. In our work so far, there has been no suggestion of either local or general untoward reaction attributable to these materials. In several of the patients, we have had occasion to use the fibrin fixation technique repeatedly, at times at intervals of many weeks. In these, there has been no suggestion of the development of hypersensitivity to the foreign protein. In some of the work with nerve suture, it has been suggested[2] that use of autologous plasma resulted in less fibrosis than did heterologous plasma. We have not used heterologous plasma as a source of fibrinogen in any of our cases. The thrombin is highly purified, and, as it is very concentrated regarding activity, only very minute amounts of the protein were needed to effect almost instantaneous clotting. It may well be that heterologous sources of fibrinogen would result in unfavorable reactions, particularly if the preparations were relatively crude.

We have not yet had sufficient experience to determine the optimum amount of fibrin to be used in the wound. In their work with nerve suture, Young and Medawar[1] found that the mechanical fixation of the tissues could be enhanced considerably by increasing the fibrinogen concentration of the plasma several fold. This did not, in their experience, cause undue fibrosis in the healing stage, even though the fibrinogen was of heterologous source. It may be that the use of purified fibrinogen solutions having much greater concentrations than that of native plasma would materially improve the results in certain instances.

In a number of our cases, as well as in studies on the use of thrombin as a hemostatic agent,[7] we have had occasion to use thrombin in wounds along with large amounts of the bacteriostatic drugs of the sulfonamide group. In these, there has been no suggestion that the drugs interfered with the activity of the thrombin or vise versa.

SUMMARY

By use of plasma and purified thrombin, fibrin fixation of tissue in operative procedures can be accomplished readily. In our experience, artificially supplied fibrin clots, obtained in this manner, have proved

to be of distinct mechanical aid in skin-grafting operations. The results in many of the cases have suggested that the fibrin also promotes healing but additional data are needed for definite conclusions on this point.

Thrombin in sterile and highly purified form is now available for clinical trial. The technique of fibrin fixation is simple to carry out and might be used to control the amount and site of deposition of fibrin in various types of operative procedures. Many possible applications immediately suggest themselves.

There have been no untoward results from the use of thrombin and plasma for fibrin fixation in the 122 operations in which we have used this technique.

The human plasma used in this work was obtained from the hospital blood bank through the cooperation of Doctor E. L. DeGowin. In more than one-half of the cases the operative work was done by one of us (R.T.T.). For the remainder of the cases, we are indebted to other members of the Department of General Surgery.

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THE TREATMENT OF BURNS AND OTHER EXTENSIVE WOUNDS WITH SPECIAL EMPHASIS ON THE TRANSPARENT JACKET SYSTEM*

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SINCE the literature on burns is voluminous and fairly up to date, we shall not attempt another very detailed description of the causes, of systemic metabolism, of local pathology, or even of the many methods of treatment. The purpose of this article will rather be to give a résumé, in more or less synoptic form, of those facts concerning the patient as a whole and his wounded tissues which we consider absolutely essential to rational management. We apologize for omitting details of certain methods of treatment which have proved valuable, but concerning which, on account of lack of space, only briefest mention can be made. The details of most of these methods will be found in a previous article.[1] Because of recent developments the transparent jacket or Theraseal system of treating burns will be described in full detil.

We shall deal principally with lesions resulting from accidental application of heat through a dry or moist medium to the surface of the body, although the term "burn" is loosely applied to excessive exposure of the skin to chemicals, electricity, friction, light, and roentgen rays.

For the most part our discussion will be confined to extensive burns, although the treatment for a small damaged area in the main will be the same as that of a larger one. First-aid measures will be mentioned only briefly.

Incidence or Prevalence.—Large conflagrations are still the greatest contributing agency, whether in war or peace. Burning vessels, burning oil on water, bomb blasts, theater and amusement hall fires are wholesale producers of burns, while airplane and automobile accidents, hot-water bottles, percolators, and open grates contribute a lesser share.

SYSTEMIC REACTION

Almost immediately following extensive cutaneous burns the patient will suffer from an extreme grade of nervous shock which will be characterized by mental lethargy or unconsciousness and rapid blood pressure. This is usually attributed to overstimulation of injured peripheral nerves and, although promptly treated, may lead to death from nervous exhaustion.

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Correlation of Extent and Depth of Burn With Systemic Reaction.—Since one of our patients, whose renal function was already known to be low, died from the effects of a "hand-sized" burn of the chest, I have not been inclined to place too much emphasis on attempting to correlate the exact size of the burned area directly with the severity of the symptoms or the prognosis. The constitutional make-up and past history should be given full weight in these cases.

It has been generally accepted that the method of Berkow[2] offers a quick and a fairly accurate means of determining the extent of a burned area as shown in Table I. This table is useful in determining what measures must be carried out.

TABLE I

RELATIVE SKIN AREAS ACCORDING TO BERKOW

	ADULT (PER CENT)	CHILD (PER CENT)
Trunk	38	40
Lower extremities	38	16
Head	6	6 (12, age in years)
Upper extremities	18	38 (12, age in years)

Other factors being equal, it is certainly true that the greater the surface burned the more severe will be the symptoms and the worse should be the prognosis. Though not proved, the idea recurs in the literature that a burn which only reddens or blisters—first and second degree (old classification)—causes more exudation into tissues and absorption of toxins and is, therefore, more serious than the deeper or charring burns. However, in the latter late complications are more serious.

When a burn involves as much as 50 per cent of the body surface the patient usually almost immediately enters into a typical state of primary or nervous shock marked by low blood pressure, rapid feeble pulse, and subnormal temperature. This is speedily followed by exhaustion of vital centers, and death. The few patients who survive burns of this extent usually die in the period of toxemia or infection in spite of the most careful treatment, however one sailor with an estimated 65 per cent burn, recently reported by United Press, is still living and grafting is still being carried on. This patient received an enormous amount of excellent treatment. It must always be kept in mind that prognosis must be related to factors like age and to physical and mental state and quality of treatment.

In a properly handled adult patient, if 25 to 40 per cent of the body surface is burned (somewhat less in children) a fatal outcome may be avoided.

While far from being the only criterion on which to judge the seriousness of a patient's condition as shown first by Underhill, Carrington, Kapsinow, and Pack[3] experimentally and clinically, most of the signs in burns, such as low blood pressure, high temperature, and circulatory im-

pairment, are due in large measure to high blood concentration. A great deal of this work was done on my patients from the New Haven Rialto Theatre Fire. Experimentally, Willis[4] showed that following severe burns the blood concentration became high, as evidenced by an increase in the number of red corpuscles and hemoglobin percentage. He further demonstrated that débridement of the burned area would prevent the development of a high blood concentration.

By means of frequent hemoglobin determinations the need of more fluids may be established and, if possible, a dangerous situation avoided. The substitution of hematocrit determinations of late has contributed greater accuracy. It is to be noted that in a recent article prepared for the Committee on Surgery of the National Research Council,[5] the authors recommend 100 c.c. of plasma for every point that the hematocrit is above 50 per cent.

TOXEMIA

Recent Status of the Burn Toxin Question.—The question of toxemia in severe burns constitutes a problem as complicated as that of the effect of internal secretions on the human system. The many articles concerning the presence of a toxin, and its nature and effect, have left the subject confused. Chief interest has centered in four problems:

1. Is a circulating toxin present in burns?
2. If one is present, what is its origin?
3. What is its composition?
4. How does it exert its harmful effects?

The fascinating story of the attempts to answer these questions will be found fully described in three texts.[6, 7, 8]

Consensus is now strongly in favor of the presence of a circulating toxin from the burned area but there is no complete and definite proof that there is only one toxin, nor has the composition of any essential burn toxin been worked out.

The dispute as to what tissue or tissues, when burned, produce toxin has covered many years. One theory is that blood when heated in the tissues may pass into the general circulation and cause symptoms. Marchand and Schultz[9] have demonstrated the damaging effect of heat on white blood cells and even plasma. Ravenna and Minissian[10] assert that blood heated in vitro to 55 or 60° C. becomes toxic when infected and produces visceral lesions identical to those found in burned patients. Robertson and Boyd,[11] who have made many excellent contributions to the subject, feel that the burned tissues are responsible for the production of a toxin which is taken up by the blood stream and that the appearance of toxic symptoms after twenty-four hours probably indicates that the damaged tissue must be in contact with living tissue before a toxic substance can be manufactured. To quote them, they believe that,

"There is a substance produced in burned tissues (in larger quantities in extensive skin burns than in those of other tissues) which circulates in the blood, either in, or closely adsorbed to the red blood cells and which causes the symptoms of toxic shock and, in some cases, death. The toxin is produced in increasing amounts following the burning of the tissues until twenty-four to thirty-six hours after injury. It is produced only as a result of burning living tissues. The toxin is most highly concentrated in solutions of corpuscles suitably treated and least in the blood plasma.

The autopsy findings of Bardeen and Weiskotten, which are quoted later under Pathology, are highly indicative that the action on organs is, according to the latter, that "of a more or less specific poison." Certainly such lesions could not be ascribed alone or primarily due to hemoconcentration.

The controlled work which I have carried out on the prevention of absorption from extensive superficial burns with absence of symptoms in guinea pigs, dogs, and human beings[12, 13, 14] by local use of vasoconstrictor drugs, notably adrenalin chloride, has convinced me that Robertson and Boyd's conclusions concerning a burn toxin are sound. The effect of the epinephrine in preventing local loss of plasma into the tissues and from the surface can only account partially for the absence of symptoms, while prevention of absorption of toxic products from the surface must also be taken into account. Most of the work performed on injection of extracts from burned tissues, as well as symbiotic experiments in which one dog is burned, while appearing conclusive, has lacked proper controls.

The recent experiments of Christophe[15] (quoted by Harkins) appear conclusive in showing that there is a burn toxin no matter if its nature is unknown and that it is fixed early in brain tissue. In these, to quote Harkins, "If the blood of a normal dog was allowed to perfuse through the amputated leg of another dog which leg is then burned, the normal dog dies." Further quoting Harkins, "In a second experiment, Dog A (whose hind legs are burned) is connected by means of the central ends of its carotid artery and jugular veins to the distal ends of the carotid and jugular to Dog B (whose other carotid and jugular are ligated and whose vertebral vessels were ligated at a previous operation). If the perfusion is carried out long enough Dog B dies with all the signs of a burn death. To show that the supposed toxin affects only the brain of Dog B, Dog B's blood was perfused through a third Dog C which did not die."

Harkins concludes significantly that the possibility of a toxin that acts on the brain early in the course of a burn is strongly suggested and that early fixation of such a toxin in the brain might explain the difficulty of its isolation elsewhere.

These experiments are in agreement with our dictum that "burns should be regarded as surgical emergencies of the first order," and may

well explain why various pressor drugs applied early after a burn, almost entirely abolish toxic symptoms.

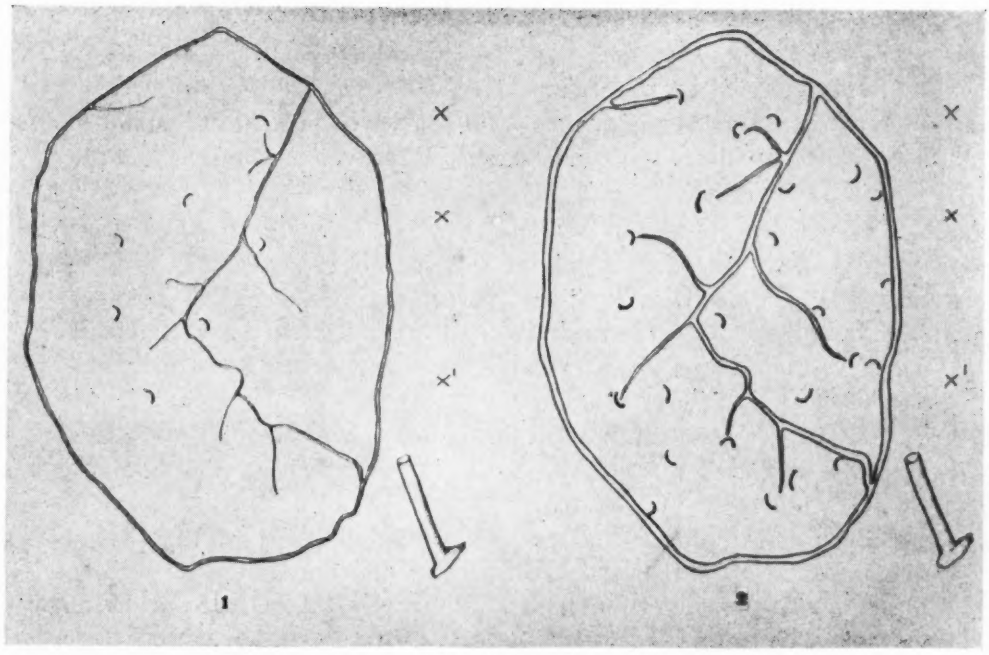
Regarding the theory that bacterial toxins produce all or a large share of toxic symptoms in burns in the secondary stage, there is no doubt left after the work of Aldrich (1933),[16] Firor,[17] Cruickshank,[18] Wilson and co-workers (1938)[19] and many others, that in one to six days the average severely burned patient will suffer from hemolytic streptococcal infection, on the surface or even in the form of bacteriemia or scarlet fever. We do not feel, however, that this fact at all precludes the probability of a toxin or toxins from the damaged tissues continuing to absorb into the blood stream and simultaneously causing additional damage.

From a great many experiments applying epinephrine on blood agar in low concentrations to hemolytic streptococcal cultures, as well as to animals, we have found[20, 21] such solutions of this vasoconstrictor drug to be bacteriostatic. In vitro the growth of the cultures was arrested. In guinea pigs, dogs, and human beings infections failed to develop on the damaged surfaces.* Identical results were obtained when adrenalin chloride, free from the chloretone usually present as a preservative, was employed.

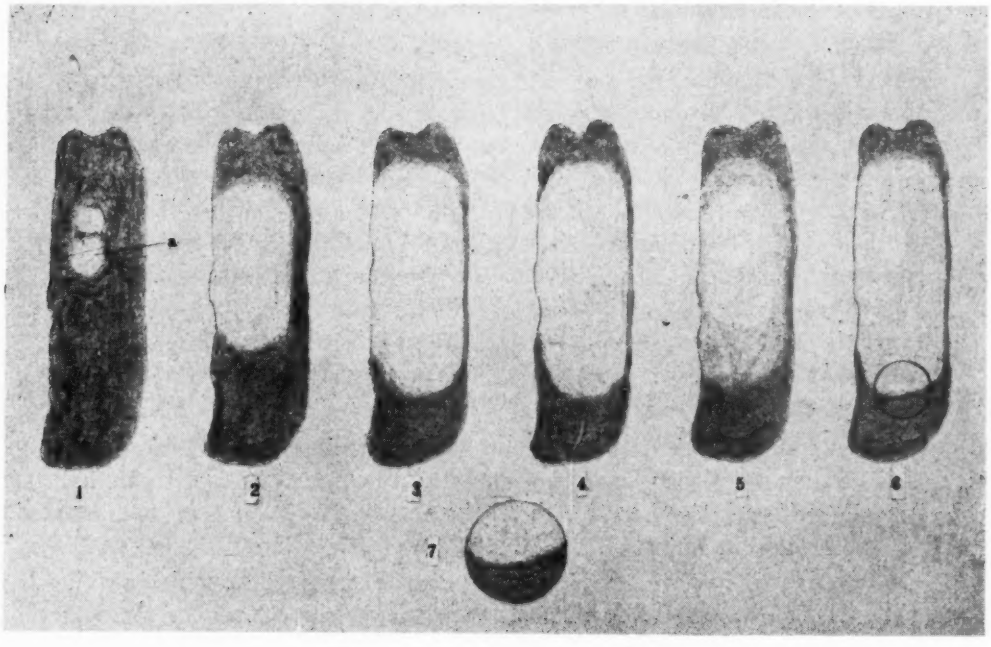
No matter whether one favors the theory of a toxin from the burned tissues or from bacteria implanted on the latter, he cannot doubt one fact—that from one of these factors or both an increase in capillary permeability is produced either directly or secondarily and that increased absorption and transudation result. I have shown[21] (see Fig. 1) that the burn of a hot needle (shaft) touching the skin at the human nail bed produces an opening or dilatation approximately three times the capillary loops normally seen under the binocular microscope with an increase in local color evident. Since the needle touches too small an area for heat to be delivered to more than two or three capillary loops, and since the dilatation is progressive, we conclude that some soluble toxin from the tissue injured by the needle is diffused locally through the capillaries to cause it (Fig. 1). Further, epinephrine applied to the nail base reddened from the dilatation of the capillaries will restore the circulation to an approximately normal condition and prevent blistering. (See Fig. 1.) On large very red surfaces from which the epidermis has come off as the result of blister formation, we have repeatedly been able to dip an applicator in epinephrine and paint a letter of the alphabet and, because of the vasoconstrictor effect, have it appear distinctly blanched against the reddened background of the burned surface.

Krogh[22] and others have shown that dilatation of the capillaries beyond a certain point causes pouring out of plasma into the tissues between the endothelial cells which are too far apart to act any longer as an osmotic membrane.

*These experiments were carried out with the assistance of Mr. Mikesell and Dr. Wherry of the Department of Bacteriology of the University of Cincinnati.



A.



B.

Fig. 1.—*A*, Effect of burn with needle at *X*-*X*,[1] in dilating capillaries, venules, and arterioles. *1*, Shows a few loops open at time of burn. *2*, Shows the tremendous increase in number and size of visible vessels three minutes after the burn. (Observations made through oil with binocular microscope on human nail-bed. *B*, Retrogression of congestion in vessels in human burn on back of hand under pressor action of adrenalin chloride. *1*, Fluid expressed from blister at *a* and adrenalin chloride 1:1000 injected into blister with needle. *2*, Shows pallor in zone surrounding blister after one minute. *3*, Pallor four minutes later. *4*, Pallor 10 minutes later. In *5* vasoconstriction is beginning to relax after three minutes more, after which time epinephrine was again injected into blister. *6*, Pallor is again very extensive after thirty-two minutes. 7, Shows area in circle magnified.

Most superficial burns producing reddening and blistering evidently cause various degrees of damage to, but not destruction of, the capillaries. The latter may dilate and pour out plasma into the tissues but later may recover their osmotic function as resolution occurs.

An article by Davidson and Matthew[23] is in line with these views. After showing that the toxemia of burns offers a particularly good opportunity for studying capillary permeability following their studies they state that, "In extensive burns there is first an increased permeability of the capillaries which explains the characteristic concentration of the blood."

Menkin[24] feels that an intermediate substance in burns causes the increase in capillary permeability rather than damage to the vessels by the heat.

Since the introduction by Davidson of tannic acid, evidence has accumulated to show that the moistening of the tanned eschar or membrane aggravates toxic symptoms. This is thought by many to be due to the solution dissolving toxic products in the membrane which absorb with the solution. Others, including Aldrich,[25] contend that the aggravating symptoms which follow moistening might be explained on an infective basis as well.

Two articles by Menkin[26, 27] seem to us to be most significant since they show that the edema fluid of experimentally burned tissues contains a substance which promotes capillary exudation emigration of leucocytes and dilatation. This substance, or the active factor, Menkin showed to be a dialyzable protein-free, crystalline, doubly refractive nitrogenous substance, not a protein, yet containing amino and carboxyl groups. Various types of inflammatory exudates, as stated by Harkins, were obtained by Menkin, either by the introduction into normal tissues of a chemical irritant, or by a burn or bacteria and all were found to contain this substance. He states his belief that it is "an intermediary breakdown product of protein metabolism probably belonging to the group of relatively simple polypeptides."

This seems to be as satisfactory an analysis as has been offered of the chemical nature of the injurious substance in burns. The fact that other forms of trauma may produce this substance seems in no way to lessen its significance in burns.

In temporarily closing this part of our discussion, considering the evidence presented on the question of toxemia we feel that a few conclusions are warranted as follows.

There is a toxin produced in increasing amounts following the burning of the tissues up to twenty-four or thirty-six hours. Its composition is split protein in nature, probably a polypeptide. Its origin, while not certain, is in all likelihood to be found in the breaking down of proteins by the heat. While the manner in which it exerts its harmful effects is not completely worked out, it is evidently absorbed by the red blood cells

and probably carried early to the brain to become fixed in the brain tissue. Damaged tissue must probably be in contact with living tissue before the toxin can be formed, as evidenced by the appearance of toxic symptoms twenty-four hours after the injury. The pathologic changes constantly found in the central nervous system, heart, liver, and other organs in fatal cases are too great to be explained by local fluid loss from the burned surface and local edema. A circulatory toxin must be assumed. Wilson and his associates[28] ruled out all causes except acute toxemia as a cause of death in thirteen out of a series of sixty-five severely burned patients and reported that in four others the toxemia was very severe. I feel that they are right in concluding that, "a specific toxin which is formed in burned tissue and absorbed into the blood stream, receives support from this investigation."

Only briefly and with apologies to those who have done detailed and conclusive work on the subject will we review the changes in the blood circulation and physics and chemistry of the blood which we regard as established.

Changes in Blood Circulation.—Baradue,[29] in 1862, stated, "The thromboses so generally found in such cases are due to the thickening of the blood, with slowing of the current in consequence of the withdrawing from the blood of the serum found in blisters." Klebs,[29] in 1877, emphasized the effect of burns on the circulation stating his findings of marked stasis in the large blood vessels and an enormous crowding together of red blood cells. In 1881, Tappeiner[29] carefully studied four fatal burns and concluded that while death was due to many factors, chief among them was loss of blood plasma through transudation. Locke's[29] chief findings in ten severe cases were sluggish flow and dark purplish appearance of the blood, an immediate increase of from 1, to four million red cells, a rapidly increasing leucocytosis to between 30 and 50 thousand white cells, a considerable destruction of leucocytes; the presence of myelocytes in severe cases and a marked increase in the number of platelets. To these cellular changes must be added the findings of Wilson and associates[30] of marked eosinophilic concentration in organs.

I have already reported the outstanding work of Underhill, Kapsinow, and Fisk on my patients at New Haven, and later of Willis, which demonstrated the great increase in blood concentration evidenced by hemoglobin increase. The latter author also showed that hemoconcentration failed to occur after débridement of the burned area.

Blalock,[31] in 1931, made the significant observation that the outpouring of fluid into the tissues (which he and Beard showed to have the same protein content as plasma) plays an important part in the reduction of blood volume and pressure. He showed that the weight of a burned extremity in a dog, over the normal unburned one, would average as much as 3.34 per cent of that of the body after time intervals of

six to twenty-six hours. This he calculates would represent 57 per cent of the total plasma. Such a loss in extensive human burns he feels can contribute greatly to a lethal outcome by producing a high degree of circulatory shock. He concludes, "It is entirely possible that such agencies as tannic acid and epinephrine exert their beneficial effects by preventing the loss of fluids, rather than by stopping the absorption of toxins." However, he never intimated that death was due solely to loss of fluids, but rather stated, "After the blood volume is reduced and the blood is very concentrated, it is likely that toxins if present even in small amounts will exert deleterious effects since elimination by the kidneys is greatly reduced."

Johnson and Blalock[32] found that associated with the loss of fluid into the tissues there was a decrease in cardiac output which, unlike the blood pressure fall, was gradual. According to their findings the blood pressure remained up until near death and then fell rapidly.

Harkins[33] experiments employing a tipping apparatus for dogs showed a definite fluid shift in burns and graphically recorded the shift. These corroborated the findings and showed that in some experiments "more than half the ultimate amount of fluid collected in one hour."

Changes in Blood Chemistry.—In addition to the changes just described in the physics of the blood, definite changes occur in blood chemistry.

Anoxia.—While usually anoxia has been shown to exist in the severe shock of burns, its importance has seemed to us to have been underestimated. Harkins gives a good summary of the work on anoxemia or anoxia as follows. Krogh,[22] in 1922, recognized the vicious circle in shock and the possible role of anoxia in it. In 1937, Bois and Hartman,[1] working on liver necrosis following burns in dogs, ascribed anoxia associated with shock, plasma loss, and hemoconcentration as principal causes of liver necrosis. Tannenbery, in 1939, found liver changes in simple cases of anoxia. Keeley, Gibson, and Pijoan observed in their experimental burns that the oxygen saturation of venous blood was reduced in all animals. It reached values of less than 10 per cent prior to peripheral collapse in those animals that succumbed. Black, in 1940, advised treatment of burns in patients with high concentrations of oxygen by means of a Boothby-Lovelace-Bulbulian mask.

The logic of this measure is found in the fact that there are plenty of red cells in the blood but that oxygenation of them is needed because of the slowing of the blood current from hemoconcentration.

Regarding the question of diminished blood flow in the shock of severe burns, not much is known, except that in shock in general it is known from the work of Freeman, Shaw, and Snyder[34] that the blood flow through the patient's hand is diminished.

Epinephrine and Suprarenal Changes.—Since lesions of both parts of the adrenal gland are so frequently found both in animals and man,

and since epinephrine and cortical hormone are both substances which affect metabolism, it is not surprising to find that the part which the adrenals play in the metabolism of the burned patient has been widely studied.

Weiskotten,[35] Greenwald and Eliasberg,[36] Berkow, Albright and others have noted early pathologic changes in the adrenals. They found glands edematous and the cut surface of both medulla and cortex hemorrhagic. Others have proved a focal exhaustion of lipoids and a necrosis to be present.

Brooks and Blalock,[38] however, present evidence to show that similar changes in the adrenal glands follow trauma to muscle and hemorrhage which lead them to conclude that they are not specific of burns.

In view of these reports, we felt it important to examine the autopsy material from fatally burned patients at Vanderbilt Hospital with reference to adrenal changes. This was done with the collaboration of Dr. Ernest Goodpasture[39] with the following significant findings in seven cases.

In two who died early (six to eleven hours after extensive burns) the adrenal vessels were congested and red cells were within and outside the capsule. Cells in medulla and cortex of one showed cloudy swelling, and an occasional collection of round cells was seen. In the other, cortical cells had indefinite outlines and nuclei appeared in places grouped in eosinophilic cytoplasm. The medullary cells were eosinophilic and vacuolated.

In five who died late (five, eight, nine, thirteen, and twenty days, respectively) after injury, one had a cavernous defect in the medulla and cortex where most of the substance was destroyed. Three had hemorrhages in the substance of cortex and medulla with varying depositions of fibrin and cellular infiltrations; three had areas of focal necrosis of varying number in the medulla and cortex.

These marked findings in both parts of the adrenals make one surmise that the functions of this important gland must be tremendously disturbed after burns and that substitution therapy may be very important from the standpoint of survival alone.

Hartman, Rose, and Smith,[37] in 1926, showed by testing the denervated cat's iris that epinephrine is secreted early in large amounts and that later autopsy revealed that there was depletion of epinephrine and of lipoids in the suprarenals.

From our studies we are forced to agree with Greenwald and Eliasberg,[36] who have shown that early after burns there is marked hyperactivity of the medulla of the adrenals. This leads at first to great release of epinephrine, which in turn leads to a marked hyperglycemia. This effect, they felt, was due to the shock of the burn acting on the sympathetic nervous supply to the glands and results in early death in severe cases.

In cases in which death occurred later than twenty-four hours after the burn, these authors found marked degenerative changes in the

adrenals with concomitant low blood sugar levels. During this stage of adrenal degeneration they claimed that a decreased amount of epinephrine entered the blood stream, thus failing to stimulate the liver in its normal glycogenolytic function. Hence, hypoglycemia was the rule. We have seen this late hypoglycemia with blood sugar reaching 17 in two fatal cases. Convulsions occurred in both and death ensued in one in spite of administration of glucose and insulin.

Before leaving the subject of damage to the adrenals in burns, we think it important to point out the apparent association of adrenal damage and Curling's ulcer. McLaughlin[8] produced partial destruction of the adrenal glands experimentally in twenty-four dogs with resultant duodenal ulcer formation. Harkins collected three cases of Curling's ulcer with adrenal hemorrhages, but of course lesions were present in other organs. The association, while not by any means invariable, is suggestive.

Application of weak epinephrine solution to a burned surface, a method which we introduced, has very little bearing on the chemical changes in the blood. Since epinephrine inhibits its own absorption as well as prevents locally an absorption of toxins, and likewise checks the local pouring out of plasma into the tissues the only resulting change noted in the blood is a slight rise in the blood sugar followed later by a slight fall.

Adrenal Cortical Hormone.—There is no particular reason to believe that the cortex suffers any less pathologic change in burns than the medulla. Weiskotten and many others have found severe changes in both. Like the medulla under the early stimulation of a burn it is logical to anyone that it will oversecrete hormone and later during degeneration secretion will diminish or fail. Many authors feel that damage to it causes the shock in burns. Space does not permit a full review of the literature on this point. Suffice it to say that Swingle and his associates[40] after much experimental work, report a pressor action of cortical hormone upon the low blood pressure and feel that it is concerned chiefly with the maintenance of capillary tone and, therefore, has a regulatory control function of the volume capacity of the circulatory system. The work of Wilson and associates[41] in demonstrating clinically the beneficial effects of this hormone has great promise and will be mentioned later.

Nonprotein Nitrogen and Polypeptide Nitrogen.—McIver's findings of a nonprotein nitrogen over 45 in fatal and under 37 in nonfatal cases are fairly typical. Apparently histamine substances account for the increase. The French school lay more stress on the increase in polypeptide nitrogen. Wilson and Stewart claim that the nonprotein nitrogen increases following burns in their patients are relatively greater than those of urea nitrogen.

Plasma Proteins.—Many writers have reported lowered plasma protein values with loss of more albumin than globulin, thus changing the

albumin-globulin ratio. This is probably due to the loss of plasma at the site of the burn. It would seem to be significant in emphasizing the importance of keeping nutrition in the burned patient at a high level and administering blood plasma. In one of the patients from the Cocoanut Grove fire, who was treated by Dr. Charles Lund, we understand that a daily diet of 6,500 calories was kept up constantly. Although a very large portion of the patient's body was burned he was doing well at the time last heard from.

Carbohydrate.—Sugar metabolism is of great importance in burns.

Hyperglycemia: The evidence for a great increase in blood sugar early after some burns is conclusive. Greenwald and Eliasberg; Schreiner, Martin; Hartman, Rose and Smith; Slocum and Lightbody, McIver, Lambret and Driessens all have reported this.[8] I have given the evidence of the former two authors that hyperadrenalinemia is responsible for this early rise but this is by no means proved. In fact, Slocum and Lightbody, and later Rudler[8] question the relationship of the adrenal glands and hyperglycemia. The former authors found blood sugar and lactic acid increased following severe burns in adrenalectomized animals. The latter pointed out that the liver also suffers damage in burns (see Pathology) and that this may be the cause as Rabboni and Cacioppo had previously hypothesized. I am thoroughly in agreement with this viewpoint. Some time ago I treated a man with a gunshot wound of the liver, which I sutured. For two weeks after this he had a very high blood sugar value which could be accounted for in no other way than on the ground of liver damage. Following this, experiments were performed on experimental animals of lacerating and crushing the liver and a similar hyperglycemia occurred which could not be accounted for by anesthesia.

Hypoglycemia: The phenomenon of extremely low blood sugar values in our experience and that of many others occurs late in burns (forty-eight hours to six days) and is an ominous sign. It is usually accompanied by generalized convulsions and death. We have already reported two fatal cases in children (see Suprarenals) with terminal blood sugar values 17 or below. Greenwald and Eliasberg have reported two, and Trusler, Egbert, and Williams, others. In one of our fatal cases the patient was given glucose and insulin intravenously with temporary benefit.

Plasma (or Serum), Sodium, and Potassium.—Evidence at hand indicates that potassium in the blood plasma usually rises after burns, but inconstantly so, only following shock, and then rarely to high levels. Shock in burns cannot be ascribed to this rise.

On the other hand *serum sodium* values have been found almost universally to be low following burns. The mechanism of this decrease reported by many has had a great deal of light thrown upon it, first by Underhill and co-workers,[53] later by Bigger[1] and by Lowdon and associates.[1]

The former showed that the sodium chloride content of the blood is greatly reduced during the stage of hemoconcentration. They felt that in the rapid interchange of fluids during the inflammatory stage of burns, sodium chloride functions prominently. Davidson[1] found low sodium chloride values in the serum of twenty-four burned patients. These values persisted until the sloughs separated and then rose to normal with a corresponding increase in urinary chlorides. This chloride crisis is similar to that of pneumonia.

Bigger stressed the significance of high blood concentration and low blood volume and reported good results in restoring the blood volume in one patient critically burned by using hypertonic sodium chloride solution intravenously. Lowdon and his associates scalded animals fatally and showed that the serum chlorides rapidly decreased before death while the sodium of the red cells tended to increase. These changes occurred regardless of previous section of the spinal cord, and removal of the brain, kidneys, or suprarenal glands. Control experiments in which only scalding was performed showed no such reduction.

By suitable experiments they showed that the sodium was being lost into the scalded tissues.

On patients, two authors, Stewart and Wilson, found that the serum sodium is rapidly restored to a normal level by administration of desoxycorticosterone acetate.

LOCAL TISSUE CHANGES AND PATHOLOGY

The older classification of burns in six degrees or in three (namely, reddening, blistering, and deeper damage) are useless in the light of clinical studies and should be discarded in favor of Goldblatt's two simple types based on end results produced by the lesion:

Type 1 or *scarring burn,* which will require special treatment to minimize scar.

Type 2 or *nonscarring burn,* which will not require special treatment.

In Type 1 or scar-forming burn, no skin structures escape destruction. In Type 2 (first and second degree, old classification) burns there is a variation pathologically from a simple hyperemia to a more severe inflammation and congestion with rapid blister formation. The stratum germinativum is markedly swollen and covered with a layer of leucocytes. If infection does not occur there is a retrogression of inflammatory signs and return to normal in from ten days to three weeks.

From all of the evidence thus far presented, it seems certain that the action of heat on the peripheral blood vessels or of a toxin from burned tissues, or both, causes the peripheral vessels to dilate and their walls to become more permeable causing local pouring out of plasma and absorption of toxin.

It is also clear that epinephrine locally applied may constrict these damaged vessels for forty-eight hours or more at a time, thus preventing

these nocuous changes. Our work shows that after seventy-two hours, if epinephrine is gradually diminished in concentration up to 1:24,000, capillary hemorrhages will not occur following its cessation.

TREATMENT

We have endeavored to describe fully the essential changes in the patient's metabolism and locally in his tissues as far as these may aid us in an understanding of the rationale of therapy.

While they are artificial and overlapping, we like to recognize three stages in the course of every patient with extensive burns. This will guide us in properly applying methods of therapy.

The *first stage* or that of *primary shock* usually begins immediately and lasts, in patients who recover, from six to twenty-four hours.

The *second stage* or that of *toxemia* lasts from twenty-four hours to twelve days. During this period the patient usually becomes febrile and blood concentration will develop unless combated. Infection may supervene in this stage and the toxemia of the infection may be added to the already existent toxemia.

Curling's ulcer of the duodenum may occur during this period or later.

Acute Toxemia Causing Collapse.—During the stage of toxemia, regardless of the size of the burn, severe toxemia leading to collapse and death may supervene at any time from five hours on. It may start suddenly or insidiously. It occurs in a small percentage of cases, but more often in children than adults and more in burns of the anterior portion of the trunk and face than those of the posterior surfaces. Nervousness marked by restlessness, vomiting, hiccup, and convulsions is manifest. The blood pressure may remain normal until symptoms of severe circulatory collapse occur as a terminal finding, but as Wilson[28] and associates have stated, "Such factors as anhydremia, changes in blood chemistry and bacterial infection have been excluded as primary or essential etiological agencies."

The third stage or that of *repair* usually covers the time from which toxemia has subsided until healing is complete. Late deaths occur in this stage from intercurrent disease. The most common complications are pyemia, bed sores, pyelitis, and nephritis. Rarer ones are septicemia, erysipelas, tetanus, and secondary venous hemorrhage. Amyloidosis, terminal pneumonia, and peritonitis also take their toll.

So much has been written on the treatment of burns and so many different methods have been presented that the literature is likely to confuse the average reader. One source of confusion, in our opinion, has been that the patient's general condition has been considered too largely to depend upon what was done to the burned surface when actually the original damage on the surface had already produced many changes in the organs and circulatory and nervous systems with far-reaching effects and complications.

Another cause of confusion and inadequate treatment is the assumption in some articles that some one form of local treatment or general treatment will satisfy all requirements, when in reality indications may change within a few hours.

In order to avoid confusion we shall divide measures of treatment into those aimed at the restoration and maintenance of the patient's general condition and the local treatment of the burned tissues; further, we shall separate small from extensive burns. To simplify the subject still further we shall try to follow definite indications based on the pathologic physiology found in each stage. Recent advances in the surgery of war burns are described, although it is realized that they may not yet have been fully tested.

Minor Burns.—Since small burns (those varying between one square centimeter and one twenty-fifth of the body surface) will not per se cause systemic changes in a normal individual, we shall dispose of their treatment first. However, severe effects and even deaths are reported in patients who are handicapped by cardiovascular, renal, or other constitutional disease. Full inquiry should be made of patients with minor burns concerning past history and when indications are discovered they should be treated in a hospital exactly as though they had a major burn.

In small burns, unless the heat has been severe enough to injure fatally the stratum germinativum of the skin, a few simple precautions will suffice. These, as published ten years ago,[1] are repeated here after being used on scores of additional patients.

"Sterilize the surrounding skin, open the dependent edge of all blisters, apply any sterile bland salve such as boracic acid ointment, cover with sterile dressing and splint any moving parts. In our experience, unless severe infection occurs, the dressings will not need to be changed oftener than at 3 to 4 day intervals. Any dead epithelium may be trimmed off at the time of the dressings."

As a substitute for this routine in burns of the face, hands, and genitalia, the Army Medical Bulletin[5] suggests applying 5 per cent sulfadiazine in water-soluble emulsion and covering with fine 44 mesh gauze and a pressure dressing of several layers of cotton waste bandaged firmly over the hands. No dressing is applied to the face or genitalia. For the eyes a 2 per cent butyn ophthalmic ointment is instilled once. The patient is then warned not to rub his eyes in order to prevent corneal damage.

Too frequent changes of dressings will damage adherent injured but regenerating tissues and will greatly increase the risk of contamination. Most surfaces which appear quite deeply burned at first will rapidly epithelize under this procedure and the delay occasioned by tannic acid for other coagulation measures will be avoided.

One exception to this procedure is that of a small deep burn. In case it is established at any time that all the epithelium including stratum germinativum is destroyed, in our opinion immediate débridement of the resulting black slough should be performed, an anesthetic being employed if necessary. Following this, intensive dakinization will soon render the part ready for grafting. Much time may be saved by the surgical removal of the deep slough since, untreated, such a slough will remain in place an incredibly long time.

Extensive Burns.—As I stated in an article published in 1923, large burns should be considered as emergencies of the first order, demanding the same immediate attention as hemorrhage from a cut vessel. In fact, since we now know that plasma is lost so rapidly from the damaged vessels of burned tissue, this statement is the more pertinent. It is gratifying that Army bulletins and textbooks at last are speaking of "First Aid" in burns. With the development of knowledge concerning the various changes produced in the system in burns and the rapidity with which these changes may occur, we are even more strongly convinced that serious burns demand immediate attention. A few hours of delay or misdirected judgment will often determine a fatal outcome. Efforts should be directed toward the prevention of certain pathologic changes known to occur rather than toward their correction after they become established.

First-Aid Measures.—When, as is sometimes the case in home or war burns, a considerable delay in getting the patient to the hospital is expected, the patient and everyone around him should be warned not to touch the areas burned, or to talk, sneeze, or cough unless the nose and mouth are covered with a handkerchief or other mask. The physician should immediately administer ¼ to ½ gr. of morphine by hypodermic and, if possible, 500 c.c. of plasma. If the patient is already showing signs of primary nervous shock, the clothes may be left on. If not, they should be cut carefully at the seams and removed, being as cautious as possible to prevent contamination. No blisters should be opened. Two sterile sheets may then be wrapped about the patient and blankets applied over the sheets. The patient should be kept reasonably warm but not too warm because circulatory collapse may result. If sterile sheets are not available, ordinary clean sheets may be soaked with rubbing alcohol for twenty minutes, rinsed in running tap water, and applied damp. In simple first aid no ointments or skin antiseptics should be applied. If these measures are carried out early and the patient is assured that many large burns get along well when properly treated, no handicap in further treatment will be encountered when he enters the hospital.

General or Systemic Treatment.—In every large burn, on entrance to the hospital, unless shock is already too profound, clothes should be removed and an estimate made by Berkow's tables (see Systemic Reac-

tion) of the percentage of the body surface involved and the depth recorded. Morphine should be given in sufficient doses and repeated often enough to relieve pain. Care, however, should be exercised not to give overdoses because too great a depression of vital centers will result. Tetanus, though a rare complication, should be considered a distinct possibility in those deep burns in which contact with the ground has occurred. In these, tetanus antitoxin is definitely indicated.

In the primary stage measures should be taken at once to combat secondary shock which will begin in twelve to twenty-four hours and which may result in blood concentration. Each patient's case must be individualized and followed closely to discover progressive changes in his physical and laboratory findings.

Administration of Fluids to Prevent Hemoconcentration.—One should not wait for hemoglobin or hematocrit determinations to indicate a dangerous level of blood concentration. However, such determinations may aid in the amount of plasma or other fluids to be administered. The Committee on Surgery of the National Research Council[5] gives the following rule: "For each point that the hematocrit is above 50 per cent cells, 100 c.c. of plasma should be slowly injected." They recommend also that if a burn involves 10 per cent of the surface 1000 c.c. of plasma should be given during the first twenty-four hours; If it involves 20 per cent, 2000 c.c. These workers feel, and we agree, that the administration of large amounts of normal saline solution will intensify edema, that administration of this and other fluids including glucose should as a rule not exceed an amount equal to plasma, and that water by mouth and food should be moderate until the stage of shock is passed and the stomach is retentive. We do not feel that whole blood transfusions are harmful if plasma is not available. Before plasma came into common use we found them very valuable. Whole blood is valuable if the patient is found to have been anemic or debilitated before being burned or if hemorrhage has occurred from a wound at the time of the burn.

Prevention and Treatment of Secondary Shock.—It is to be pointed out that during the period of secondary shock an aggravation of symptoms such as vomiting, elevation of temperature, lowering of blood pressure, and weak and thready pulse indicate the development of an acute toxemia designated by Harkins as a "third stage acute toxemia." In our discussion this is regarded as simply an aggravation of symptoms of toxemia already present.

Adrenal Cortical Extract: Harkins[8] states that this substance "offers more promise in the treatment of burn toxemia than any other remedy." His excellent summary of the literature is followed and acknowledged here. Introduced for the treatment of shock in burns complicated by fractures, in 1933, by Bannick, its use was reported by Wilson, Rowley, and Gray in 1936. They report recoveries from collapse in three out of four cases treated in Edinburgh. Harkins reports a severe case in which the patient was treated with cortate or synthetic desoxycorticosterone

acetate,* intramuscularly, every four hours for five days. In this case there was no shock at any time. Ivory, in 1940, also reported favorable results of the extract in four cases from the Hindenburg disaster.

Cope and Rhinelander[70] used adrenal cortical extract† on two patients severely burned in the Cocoanut Grove fire. The first had 70 per cent of the body surface burned and suffered severe pulmonary damage from inhalation. He received the extract intravenously approximately seventeen hours after injury. The second, with 22 per cent surface burns and pulmonary edema from severe inhalation burns, received two doses intravenously about fourteen hours after injury. Both had a fatal outcome. While these authors admit that these cases were a severe test, they feel that there was "no clinical evidence that the hormone in any way influenced the course of the disease." They state that they have treated selected burn patients previously in the hospital with the cortical extract and that "no unequivocal benefit has been obtained from its use."

Apparently from Rhoads, Wolff, and Lee's[8] work, the action of the cortical extract is to restore the capillary walls to their normal state of permeability and thus to prevent protein loss.

Melvin[8] and his associates recommend its use in the form of eucortone for 100 hours after the burn, 1 c.c. every two hours for a child and 2 c.c. every hour for adults. They believe that until the extract has been used on more cases and is on a surer basis, it should be considered as an adjuvant measure and not as a substitute for proved and recognized preventive treatment in toxemia and burns.

During the secondary or toxic stage, adrenal damage may lead to hypo-adrenalinemia, as mentioned before, according to Greenwald and Eliasberg. This may lead to marked hypoglycemia. They feel that epinephrine should be given frequently in this stage and that at the same time glucose should be given along with large amounts of fluid. We have had two such cases in children with marked hypoglycemia. One with a blood sugar finding of 17 died in spite of the administration of glucose and insulin. The other recovered. It is our belief that many patients may be saved by keeping fairly frequent determinations of epinephrine, glucose, and (as we shall show) serum or plasma chlorides.

We have quoted the work of Lowdon, Underhill, and Bigger, who showed a lowering of the plasma or serum chlorides in the secondary stage. The latter relieved toxic symptoms in patients by administering hypertonic saline solution intravenously. When blood determinations show this state to exist, certainly chloride should be administered, but one should always remember to give sufficient fluid with it to prevent too great a loss of fluids through its diuretic effect. If isotonic or normal solution of saline are to be administered, they should be given in the form of gum saline in order to prevent edema at the burned site and the washing out of serum proteins from the circulation.

*Produced by Schering Corporation.
†Produced by The Upjohn Company.

Anoxia.—If the patient develops anoxia and is found to be cyanotic, oxygen should be given at high concentration in a Boothby-Lovelace-Bulbulian mask.

Determination of Chemical Changes in Blood.—Certain tests which are routinely employed in departments of biochemistry and pharmacology are referred to here in the hope that they will encourage others to report their findings. From this it is hoped that the present conflicting opinions concerning blood findings may be resolved and that therapy in the future may be put on a firmer basis.

Epinephrine.—Although colorimetric tests have been described for epinephrine, these, on the whole, have been misleading. The amount of epinephrine in the blood is determined on the iris of the sympathectomized cat. The reaction is compared with that given by a known standard and the unknown is diluted until the concentration is determined. The determination of epinephrine, especially late in the course of the burn, should be made fairly frequently in order to administer it in the blood stream if necessary.

Adrenal Cortical Hormone.—Cope, Nathanson, Rourke, and Wilson[71] consider 17-ketosteroid excretion to be an index of adrenal cortical function. They took the proved increase of these steroids in the first days after a burn to mean increased cortical activity and the subsequent decline, a lowered or depressed activity.

Serum Chlorides.—Serum chlorides are determined by the Van Slyke-Sandroy open Carius method.[72] This is modified by adding 1 to 2 drops of strong KOH to 1 c.c. of serum and by evaporating to dryness before digesting.

Blood Sugar.—Blood sugar is determined by the Miller-Van Slyke method.[73] Since the indicator called for is no longer available, a new indicator called o-phenan-throline is used in the form of a ferrous complex.* The test is done in transmitted light which helps one to note the end point.

Systemic Chemotherapy.—Since the danger of contamination is so great and infection so common in burns, measures to combat infection with its attendant added toxemia should be carried out from the start. Whole blood in small quantities is a definite aid in lessening the chance of infection and in secondarily building up the patient's hemoglobin percentage and red blood cell count. Already sizable series are being reported in which sulfanilamide, sulfadiazine, or sulfathiazole has been used by mouth with great reduction in infection. Wilson and his coworkers give sulfanilamide orally as a prophylactic measure beginning the third day and stepping the amount up at the first sign of fever.

Since vomiting occurs from the toxemia of a burn and this is likewise a sign of the patient's sensitiveness to a sulfa drug, it is obvious that if one of the drugs of this group is used, its concentration in the blood

*This may be obtained from the G. Frederick Smith Chemical Company, Columbus, Ohio.

stream must be watched very carefully. The use of these drugs is hazardous in burns when blood levels are not very carefully watched.

Maintenance of Nutrition.—During the stage of recovery, systemic treatment should be directed toward providing adequate nutrition to combat anemia and loss of weight. A high caloric diet, rich in proteins, will help greatly. Vitamins must be supplied in sufficient quantities also. Two standard multivitamin tablets daily will suffice to satisfy average needs. Fairly frequent blood transfusions and iron preparations should be used to combat the anemia so common in this stage.

In order to illustrate the importance of maintaining nutrition in burns we cite one recent case in which the patient survived the Cocoanut Grove fire in Boston. This patient had more than 50 per cent of his body surface burned. He has been given 6,500 calories daily—a large portion of it through the intravenous route. His daily caloric intake was said to equal about three pounds of meat. At the time of this communication he is still doing well and grafting is already being done. His physicians, Dr. Charles C. Lund and Newton C. Browder, feel that the nutritional treatment was the most important single fact in his management.

Local Treatment.—As has been stated under Pathology, Bardeen and Weiskotten found many severe pathologic changes in the organs of extremely burned patients as early as four hours after injury, these changes resembling those caused by a toxin like a diphtheria toxin. From this, two facts are self evident: One, that burns should be treated immediately like other surgical emergencies, such as hemorrhage; the other, that in many burns which are seen by the surgeon hours after the injury the treatment of the patient's general condition may have become of greater immediate concern than that of his burned surface, no matter how important the latter still may be. No local treatment can abolish the effect of absorption of toxins into the circulation or blood concentration from edema and fluid loss after these changes have occurred. While the literature on treatment of the burned surface is crowded with a perfect maze of new and nonofficial substances and combinations of substances, we believe that we can show that one increasing purpose runs through it all. On the whole we feel that progress is becoming surer now that some of the fundamental facts concerning the burned surface have become known and the principles guiding our management of its needs are better understood. We do not plan to reiterate all of the data concerning various treatments proposed, but rather to suggest principles and apply them in such a way as to discover, amidst a host of unessentials in the literature, which method or methods at present come the nearest to satisfying the best indications of local treatment.

There is every reason to believe that tissues traumatized from heat have much in common with similar tissues injured from other causes. It is likely that whatever the cause of damage to cells, a shock-producing substance or substances are liberated from them; in fact, my colleagues, Brooks and Blalock, have shown that changes in the suprarenals similar

to those in burns are also produced by trauma to muscle and by hemorrhage into tissues. It is well recognized among clinicians that severe superficial contusions, rough handling of muscle, or movement of loose ends of bones between injured muscles during transport of fractures produces shock which cannot be entirely explained on a basis of primary overstimulation of nerves.

Burned or scalded tissues may be considered to differ from extensive deep lacerations only in the fact that in the burn there is more devitalized and especially more doubtful tissue. In the burn, because of the variability of exposure of different parts of the skin surface and the protective action of underlying vessels in rapid convection or diffusion of the heat, the amount and depth of damage are usually very variable and hard to estimate at different points on the surface. The depth of damage from bomb flashes and explosions such as that of the Hindenburg are particularly difficult to estimate. Unlike deep laceration where the rule (at least before sulfa therapy came in vogue) was early complete débridement of all dead tissue in burns, it is certain that unless charring has occurred this procedure will result in loss of much valuable regenerative tissue. Another difference from the lacerated wound is that in a burn the coagulated surface tissues may be used to protect temporarily the deeper tissues from infection.

Principles Underlying Local Treatment.—Keeping these facts in mind a few principles which seem self-evident should be applied in the treatment of a partly burned surface.

1. Cleanse the surface and get rid of dead and devitalized tissues as soon as is safe.

2. Prevent absorption of toxin from the surface by chemical surface coagulation, pressure, or physiologic vasoconstriction.

3. Provide covering in order to:

prevent exposure of sensitive nerve endings and damaged epithelium to injury
prevent excessive heat loss
prevent leakage of plasma from damaged vessels to the surface and into tissue spaces
prevent further contamination
contain antiseptic for combating infections

4. Put the part at rest in the position of function until movement is indicated.

All of these principles may be condensed into three:

1. Protection and rest for the damaged part
2. Obliteration of capillary exchange at the site of injury
3. Antisepsis

It is our belief that the method of treatment which applies these principles in the fullest degree will give the best chances of recovery with minimum loss of function.

It must be recognized, of course, that burns must be individualized for treatment to do the most good. Thus, it is well agreed that tannic acid should not be applied after twenty-four hours, and that burns of the face, hands, and genitals do very badly when tanned; likewise, that transparent jackets may be used to greatest advantage on burns of extremities.

Evaluation of Methods of Local Treatment.—No matter what later procedure is to be carried out, burned surfaces should be cleaned as early as is compatible with the patient's general condition. The procedure recommended by Owens[43] is as follows:

"The surgeon scrubs and drapes the patient as if for an operation. Using only morphine for analgesia, the burned areas are then washed with thick suds of bland white soap, sterile water and large pads of absorbent cotton. A gentle rotary motion is used in the cleaning process." He then adds the details of débridement by sharp dissection. To these details of cleaning of the entire area I would add that the soap suds should be thoroughly washed off with an abundance of normal saline solution and that then the surrounding skin should be dried and painted with some good skin antiseptic like aqueous zephiran, metaphen, or merthiolate.

From this point on, opinions are at great variance as to the best time to accomplish the remaining part of Principle 1 or débridement.

Immediate total débridement under anesthesia, as advocated by Willis, would be ideal for prevention of toxemia, but has been largely given up because of considerable operative risk and because islands of epithelium in hair follicles and sweat and sebaceous glands may be sacrificed which might have been saved. A cautious débridement under morphine only, as practiced by Owens, largely obviates these disadvantages.

Delayed partial débridement was first employed by us in 1934.[1] This consists in delaying the removal of damaged tissue except dead epidermis until sloughs have become definite. Then as large a portion as it is felt the patient can tolerate to have removed is surgically excised at one operation under nitrous oxide-oxygen anesthesia and this area is dakinized. This process is safely repeated with skin grafting at the site of each previous excision until the patient is entirely healed. In our cases this procedure has proved safe for both the patient and his tissue.

To carry out Principle 2 and prevent absorption of toxin from the injured tissues, several methods have been designed as follows:

(a) *Mechanical Pressure.*—The method of controlling or partially blocking capillary interchange and therefore of limiting absorption by mechanical pressure was discussed by us,[45] in 1923, as follows: "I first considered employing light pressure interrupted by periods of relaxation, as a means of exerting a tourniquet action on the capillaries, but the

technical difficulties of applying inflatable rubber jackets or of immersing insulated patients in heavy solutions have made other methods of treating patients more valuable clinically.''

It is interesting that in the use of hypertonic saline tubs or baths, as popularized by Blair and Brown, a certain head of pressure is exerted for the tub period of the patient's routine, although this element of pressure is not mentioned by the authors as a factor in the treatment. At the point of deepest immersion this might reach a head as high as 35 cm. of salt solution (more of water), which figure approaches normal capillary pressure.

In lieu of tannic acid, the Committee on Surgery of the National Research Council advises a pressure dressing over an appropriate antiseptic dressing for the hands, and Owens,[43] in his outline of treatment of burns after early or late débridement, applies (over a first layer of 44 mesh wet gauze and a heavy dressing of mechanics waste and a layer of cellophane) a three inch roller bandage with ''considerable pressure.''

(b) *Coagulation of Proteins on the Surface by Chemicals* (Tannic Acid).—Many substances have been advocated for this purpose since Davidson published his masterful articles on the subject of tannic acid. While for some it has been claimed that there is less likelihood of troublesome infections under the crust, for none has a better membrane been claimed. The author summed up its action in these words, ''It precipitates proteins, alkaloids, some glucosides and the salts of heavy metals. It forms a more or less stable compound with the protein constituents of the body fluids and cells. When applied to a burned surface in dilute solution, further penetration into the deeper lying protoplasm is apparently prevented by this action and the true astringent effect appears to be limited exclusively to the most superficial layers of tissue.''

I still feel that tannic acid is an extremely valuable adjunct to burn therapy at the war fronts, although I feel that its use is contraindicated in burns of certain depths (third degree) and certain locations (face, hands, genitals, and feet). There is no longer any question of its great reduction of mortality in the period of toxemia over ordinary dressings. Thus, the contention of Davidson that the toxin of whatever nature is locally precipated and held in the membrane appears to be borne out. That this decreased mortality is not due to prevention of infection is shown by the rapid return of toxic symptoms when wet dressings are applied to the membrane.

If all burns were superficial and could be treated by Davidson's simple gradual tanning specifications, results, while slowly obtained, would be excellent. Davidson warned against deep caustic action of strong solutions which tanned in a short period of time. On the face, because of the eyes, tannic acid is dangerous and the membrane on hands and fingers, on account of the immobilization produced for so long a time, is disabling. On deep burns the tannic acid membrane may imprison

organisms which produce deep burrowing infections. Consequently, its use is not desirable in such cases, particularly since the membrane will have to be excised before grafting is done.

Tannic Acid-Silver Nitrate.—In 1935, Bettman introduced the addition of 10 per cent silver nitrate to the initial application of 5 per cent tannic acid to hasten the tanning and, as he claims,[47] to save lives that would otherwise be lost from absorption of toxins, hemoconcentration, and infection if a slower method were used. Tannic acid-silver nitrate treatment is recommended for use except on face, hands, and genitals by the Committee on Surgery of the National Research Council.[48] Harkins[50] feels that "one advantage of the method cited by Bettman is rather difficult to prove; namely, that the use of tannic acid plus silver nitrate over a short period of time is less destructive to skin islands than is the use of tannic acid alone over a period of time. It is possible that a lessened incidence of infection might account for such results. He quotes Aldrich as saying, "The disadvantage of using silver nitrate is that it converts every second degree burn into a third. Exposed injured dermis cannot stand being in contact with silver nitrate. An epithelium that would live and spread is destroyed by this method." Bettman claims just the opposite, namely "stimulation of epithelization" and "less skin grafting."

Many other substances, most of which are antiseptics and will precipitate proteins such as gentian violet and many other dyes will be discussed under Principle 3.

(c) *Prevention of Absorption of Toxins by Physiologic Action, Namely by Vasoconstrictor Drugs.*—In an article in 1923, on "Restriction of Rate of Flow and Interchange in the Capillaries" we showed that the absorption of injurious substances could be prevented, especially in superficial burns, by vasoconstrictor drugs, notably epinephrine. Through the work reported in this and a slightly later article, it was proved experimentally and clinically that prompt and lasting (seventy-two hours) restriction of the rate of flow and interchange in capillaries may be produced over large burned surfaces devoid of epithelium by constant or intermittent local applications of vasoconstrictor drugs, notably by epinephrine, in very weak solution. Locally applied, it was shown that epinephrine will very largely, if not completely, inhibit its own absorption by direct action on the most superficial vessels not severely injured. Its use was suggested for the purpose of preventing absorption into the general circulation at any one time, of a dangerous quantity of symptom-producing substance from the surface. Following this, we showed that epinephrine chloride in concentrations harmless to tissues would stop or greatly inhibit absorption of various dyes, crystalloids, and alkaloids, as well as soluble bacterial toxin and cobra venom from abraded or wounded surfaces of animals.[52] It was demonstrated that animals with very extensive burns (35 to 40 per cent)

would survive with a minimum of shock when treated with moist epinephrine compresses 1:8000, while controls treated with normal saline solution would die in twelve to eighteen hours. Underhill and co-workers[53] showed in experimental burns in rabbits that when strychnine is injected into the burned area up to an hour following the burn, it is rapidly absorbed and produces convulsions. After this latent period during the next seventy-two hours, absorption of strychnine and phenolphthalein is present but slower than under normal conditions. This they took to mean that capillary permeability was increased early, giving rise to rapid absorption and later it is increased in the outward direction "so that substances pass more readily than normally from the capillary to the wounded area giving rise to edema" which slows up absorption.

This work serves to corroborate ours in showing that surface absorption must be very rapid in the first period after a burn and that the latter, for this reason, constitutes an emergency which should be treated at once. It also shows that absorption, while slower from an edematous mass than from uninjured tissues, may still be appreciable over a period of time. With epinephrine applied to the surface capillary permeability and exchange is diminished from the start. Fig. 1 shows how heat, even at a distance, opens human capillary loops and how epinephrine closes them.

Several children with burns as high as 25 per cent of the total body surface were treated with local epinephrine compresses.* In these, adrenalin chloride 1:8000 was injected through Carrel tubes to soak light gauze packs covered with cellophane. Toxemia was strikingly absent in these cases and all survived. That the epinephrine was effective after twenty-four hours was shown by washing it off with saline solution and after two hours painting a figure 2 on the then red area with fresh epinephrine on an applicator. The figure 2 then stood out blanched against the red background. After forty-eight to seventy-two hours, concentrations of epinephrine were diminished gradually to 1:24,000, at which point saline solution was substituted without the development of toxemia. The tapering off prevented the development of capillary hemorrhage which, while rarely of any significance, might occur if the epinephrine effect was suddenly interrupted. Dr. C. A. Mills, who studied the blood chemistry on these cases, showed that so little epinephrine was absorbed that the only change detectable was a slight increase in blood sugar. It was, however, pointed out that the carbohydrates should be continued to avoid the late hypoglycemia which may develop due to adrenal damage in any patient with burns. The use of epinephrine was thought to be contraindicated and was not used in patients who had hyperthyroidism. Reports of this and further work were published in two articles.[12, 55]

McCollum[57] reports the use of this method in several European clinics and states that he has applied epinephrine to fresh burns with . . . "a

*On the Pediatric Service of the late Dr. Kenneth Blackfan at the University of Cincinnati.

reduction in the amount of tissue fluid loss.'' He feels that the absorption of any toxic products in the burned area is thereby kept at a minimum. He finds that ''the amount of adrenaline absorbed is also very small because of the local constriction of the vessels.''

Epinephrine has no broken-down or oxidation products which are toxic. Its bacteriostatic action on common pyogenic organisms has been reported. Burned areas which have been treated by us experimentally and clinically have remained remarkably clean and their healing has been very satisfactory. In the early days the expense of the continuous use of epinephrine on such large gauze dressings over burns for three days proved very great. A less expensive way in which to use it was sought so that it might be employed more widely. It is felt that our work of perfecting transparent jackets, to be described, has accomplished this. For the first time, with these Theraseal jackets small quantities of weak epinephrine solution may be made to affect large surfaces for long periods without waste, because they are sealed in an airtight jacket.

Provision of Covering.—This leads us to Principle 3, namely to provide covering, the accomplishment of which serves to prevent further contamination, to prevent exposure of nerve endings to injury, to prevent excessive heat loss, to lessen loss of plasma from damaged vessels to the surface and into tissue spaces, and, if desired, to contain an antiseptic for combating infections.

Many types of covering have been suggested, from bland ointments of boric acid covered by fine gauze mesh as employed at the Massachusetts General Hospital on the Cocoanut Grove victims, to the more complicated methods of coagulating the surfaces to form an adherent form-fitting encasement. Then we have the method of alternating dressings with hypertonic saline immersions in tubs.

Although we are aware of the fact that in some clinics cleaning of the fresh burn is omitted, we still believe that there is less of an aftermath of infection if simple cleansing measures are carried out, as outlined, as soon as the patient's condition warrants.

In the matter of dressings we feel that the trend is definitely away from frequently changed dressings as occasioned by soaking in tubs or by ambrine technique which requires a tremendous amount of time on the part of the medical and nursing staff, and toward more occlusive, longer enduring coverings with less frequent changes.

Coagulating or tanning methods, such as furnished by tannic acid alone or in combination with silver nitrate, various dyes such as gentian violet, acriflavine or combinations of these, all form covering membranes of varying degrees of thickness and flexibility. Some of their advantages and disadvantages have been discussed under Principle 2. With the tanned membrane present it is true that no other covering except a moderately heated cradle to exclude air from the body is required and further contamination, heat loss, and leakage of plasma from the surface is pre-

vented. Nevertheless, because of the hardness of the eschar or membrane, deep infections may be masked under its surface. Another disadvantage is that healing or reparative measures may be delayed by the slow separation of the membrane. We have pointed out its dangers when used on the face, hands, and genitals.

Other substances, such as gentian violet and triple dye (brilliant green and acriviolet) also form covering membranes but these membranes are much thinner and more pliable than the tannic acid membrane. Also they have the proven advantage of being antiseptic, which reduces the incidence of infection. If pus forms under these membranes it dissolves the latter and breaks through. I have had the opportunity of following burns treated by gentian violet and triple dye and feel that both are of definite value. Leriche[8] feels that because of its antiseptic power, mercurochrome is the dye of choice for infected burns. One drawback to all dyes is that they stain and ruin almost every article with which they come in contact. Although a minor objection, this is a very real one.

Probably the reason that the Committee on Surgery of the National Research Council recommends tannic acid-silver nitrate as one method for treating most burns is that this offers an easy, quick, fairly safe method which can be carried out well with light materials in the field and which saves dressings.

Antiseptics used in treating burns besides the ones mentioned previously are the sulfa derivatives and Dakin's. Pickrell[8] claims to have obtained excellent results with a sulfadiazine spray which does not stain or coagulate. This drug, sulfanilamide in solution, and Dakin's solution are the drugs which have proved most useful in the cleaning up of infected surfaces before grafting.

Wet dressings are very uncomfortable unless cover is provided over them. Cellophane over gauze is one form of cover which has been used for years. Transparent jackets without gauze are by far the most modern form of covering. The development of this form of dressing together with its clinical application which has been described in three previous articles is now given in greater detail.

THE TRANSPARENT JACKET SYSTEM

Development.—My observations on the avoidance of secondary infection in acute pleural empyema by the use of closed methods in contrast with open methods of drainage, as well as other observations on the effect of pressure on the peripheral blood vessels in preventing absorption from wounded surfaces, led me in November, 1935, to develop a new method of treating extensive burns and other wounds in which the conclusion from both studies could be clinically applied.

The apparatus first employed consisted of a rubber jacket. A few weeks later jackets of specially made transparent rubber were used. In 1937, completely transparent jackets of Pliofilm* were employed and

thin but rigid cylinders of cellulose acetate were used for skin grafts. When pliofilm became scarce because of rubber shortage we adopted the more durable miracle glass plastic Krestex cloth which is also transparent.

The first patient was treated by this jacket method in early December, 1935 (See Case 1, Fig. 2*D*). The second patient was treated during the same month (See Case 2, Fig. 2*A*, *B*, and *C*). Both patients had burns which were treated by skin grafts within the jackets. Results on both were very satisfactory.

Literature on Jacket System.—A preliminary clinical report of the jacket system of treating extensive wounds was given at the Vanderbilt Medical Society, March, 1936, when transparent jackets were shown for the first time and this was reported in April, 1936.[59] As in any new work, the clinical apparatus was difficult to obtain at first. Thus, much time and effort were used in getting the jackets properly made. The first step was the perfecting of a transparent material which would be soft, pliable, strong, chemically resistant, and fabricable into the various forms required.

I was able,† in February, 1936, to have made a slightly yellow-tinged, but completely transparent, rubber sheeting of which I made many satisfactory jackets. These served the purpose well until 1937, when I obtained‡ a supply of extra thick pliofilm which was colorless and even more transparent than the rubber material and which could be stuck together permanently at the seams by heat or cement. Inlet and outlet tubes were fitted hermetically at different points through the material by compression washers such as those used in fitting a valve to a bicycle tube. In others, rubber or plastic tubes were sealed into the jackets as outlets.

Realizing, in 1937, that the treatment of wounds within the jackets presented many new and interesting problems which needed study, I obtained a grant for this purpose from the Committee on Therapeutic Research of the Council on Pharmacy and Chemistry of the American Medical Association. As our experience increased, additional problems presented themselves which have been thoroughly investigated. One of these was the determination of the effect of pressure within the jackets to skin grafts. It has been found, by placing a mechanical stage within one of the jackets, that sufficient positive pressure can be applied to a piece of moist skin placed on the stage to hold it firmly in contact without the employment of sutures. The pressure is exerted equally over the entire surface and would be maintained for a period of time. If for any reason the pressure should be lost, it can be regained by interrupting its source and applying it again.

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*Produced by Goodyear Tire & Rubber Co., Inc.

†Through the kindness of Mr. Willard P. Siberling of the rubber company which bears his name in Akron, Ohio.

‡Through the kindness of Mr. Erikson, of the American Hospital Supply Corporation of Chicago.

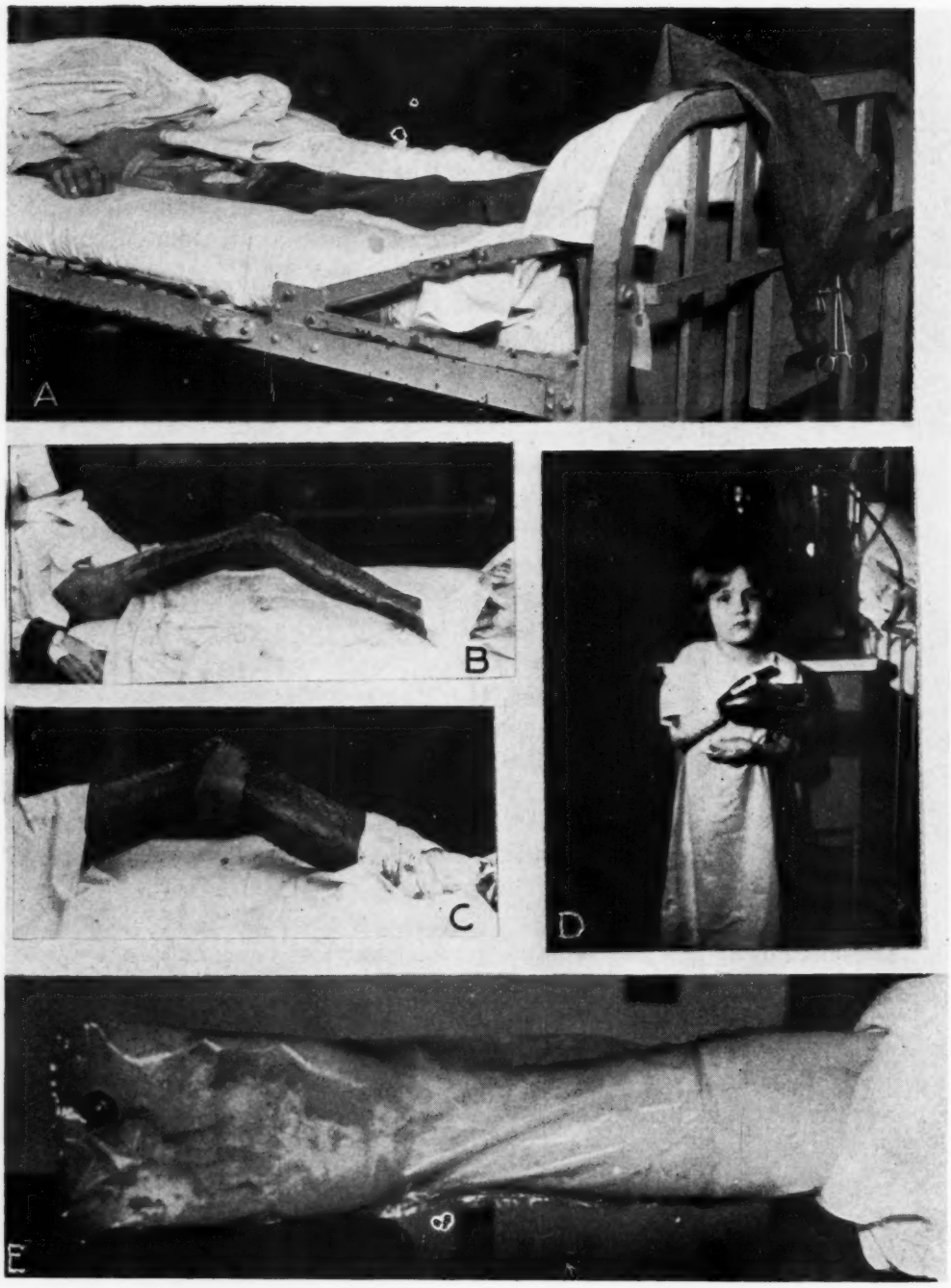


Fig. 2.—Evolution of transparent jacket method. *A*, Dec. 11, 1935, burn of thigh and leg (Case 2) treated in sterile rubber inner tube. *B*, Condition of same patient before grafting. *C*, Showing take of split-skin graft of three-quarter thickness to popliteal space, pressure on which was supplied by compressed air within tube. *D*, Case 1, Dec. 5, 1935, large rubber surgical glove forming jacket to contain pressure over skin grafts of palm and fingers. Air pressure of 20 cm. of water exerted from water bottles. *E*, Completely transparent pliofilm jacket with tube connection shown at section on Surgery, Southern Medical Association Meeting, Oklahoma City, Nov. 16, 1938.

In November, 1938, in a paper read at a meeting of the Southern Medical Association, apparatus and slides showing the successful treatment of extensive wounds in jackets, both of the pliable and rigid type, were presented. It was stated that while visibility in the jackets was afforded at all times, all other dressings to the wounds were avoided. It was also shown that pressure from the introduction of filtered air within the airtight jackets would hold skin grafts in contact with the wound while exerting easily regulable capillary pressures equally on every millimeter of surface, thus avoiding bulky marine sponges, mechanic's waste, rubber tampons, and other materials used for this purpose.

In February, 1939,[60] in advocating its employment for wounds of the extremities, we stated that "by its use the very atmosphere surrounding the wound, i.e., temperature, humidity, solution or gaseous content, positive or negative pressure and light conditions may be varied at will while the wound is studied through the jacket under the naked eye and the total exudate collected for study. Exact pressure may be applied to skin grafts and no other dressings applied."

During a brief visit to my home in 1940, Sir Hubert Wilkins, the famous explorer of both the Arctic and Antarctic became interested in the pliable lightweight transparent jackets for use on the extremities and stated his desire to take some of them with him for emergency purposes on his next trip.

Recently two English authors[62, 63] have reported their use of pliable lightweight transparent jackets, or "envelopes" as they term them, on burns and wounds during 1940. These are the same in every essential detail, in principle as well as in application, to the pliable ones which we developed as outlined previously in November, 1935, and on which we published three reports[59, 60, 61] between 1936 and 1939. No reference is made in their articles, nor in any references to these articles in journals or texts, to this original work which preceded theirs by five years and was published more than four years before. No doubt this is an inadvertence due to war conditions, and, now that attention has been called to it we feel certain that correct references to the original transparent jackets will be made in any future publications on this method.

The results achieved with these jackets seem to us to justify our feeling that the method embodies principles and apparatus with which to carry them out which make it unique and of very real value for general use.

Development of Principles on Which Method is Based.—The system of treating extensive wounds such as burns in transparent jackets is a logical development from past methods and involves principles which, over a long period of time, have been gradually evolved for wound treatment by many surgeons.

In the past the status of the treatment of extensive wounds from burns, frostbite, and mechanical trauma has been very unsatisfactory. The mere mention of them usually brings to mind many unpleasant sessions when the removal of massive dressings soaked with fetid pus resulted in almost unbearable pain and frequently caused a considerable loss of blood to an already debilitated patient.

Step by step, surgeons have been persuaded to adopt methods which will make the dressings of such surfaces less frequent and less painful. The Schede blood-clot operation for osteomyelitis was perhaps the first step in this direction. Then came Halsted's use of gutta-percha tissue to prevent the sticking of a wound to the dressings. Later came the direct application of elastic adhesive to an ulcerated surface with infrequent dressings, advised by Wright,[64] and others. Still later we come to the doctrine of Orr[65] of the treatment of osteomyelitis and other wounds by drainage and rest. In his first book on the subject we find the following statement, "If dressings are done at intervals of several weeks instead of daily, it is quite possible for the surgeon to give the necessary time to see that his original ideas in regard to the position of the limb, splints, apparatus, etc., are strictly carried out and to have the dressings done under his own eyes so that proper rules of technique and aftercare are strictly observed." I quote this author further in saying:

"The different effect on the wound itself is shown by the fact that upon examining the wound for the first time two or three weeks following operation, there is found to be usually less discharge than is found at each dressing when they are changed frequently. This seems to explain why the absorption is less also when the infrequent dressing method is employed."

And further, "Among the advantages which should be emphasized for the treatment of these conditions by drainage and rest alone, none is more important than the relief afforded the patient."

Again I quote Orr as saying, in 1930, in Detroit, "Do not disturb the wound or the part except for definite complications."

Treuta's[66] success in treating compound fractures and other war injuries in plaster casts left on for long periods is but another link in the chain of evidence that a closed method with very infrequent dressings is of definite value.

One may easily see from the trend of all these opinions that the teaching of modern surgical thought is away from frequent dressings especially of the porous type, and toward infrequent ones of a type relatively impervious in the inward direction, which cause less pain. Perhaps the greatest danger in the new era is that the surgeon, in his knowledge that less frequent dressings are advantageous, may overlook complications until grave symptoms have developed. In my own experience, however, this latter occurrence has been very rare.

In an article in 1930,[67] in speaking of the advantages of closed methods of drainage over the open methods for treatment of acute pleural em-

pyema, I wrote: "It (the closed method) seals the pleural cavity and does away with the inconvenience of frequent dressings and the danger of secondary pleural contamination; . . . and it eliminates the development of chronic empyema from acute cases. . . ."

It is an arresting thought that the great development afforded the surgical field in the realm of asepsis in operations by the use of rubber gloves, first by Bloodgood and Halsted at Johns Hopkins, in simple terms consisted of jacketing the operator's hands so as to keep contamination from the freshly damaged tissues. Is it not as important, or even more so, to jacket a wounded hand or other part of the body from the many sources of contamination to which it would otherwise be exposed? Was not Lister's main idea that no extraneous organisms be introduced into a wound during surgical proceedings? Our very first patient treated in this manner was a child whose injured hand was encased and sealed safely in a large rubber glove. All later forms of jackets involve the same fundamental principles but add the convenience of transparency. In all, the protection afforded the part is basic.

The present jackets we employ all make frequent dressing unnecessary and even undesirable and likewise make the development of unseen complications, such as the deep abscesses which may arise under a surface tanned with tannic acid, very rare by keeping the wound surface under clear vision, soft and palpable at all times.

Résumé of Work on Capillary Blocking.—From records of experiments my work along this line dates back to 1920. In an article in 1923, this statement is made, "I first considered employing light local pressure interrupted by periods of relaxation as a means of exerting a 'tourniquet' action on the capillaries, but the technical difficulties of applying inflatable rubber jackets or of immersing insulated patients in heavy solutions have made other methods appear more valuable clinically." Many years after this I found out that in 1834, Junod had applied an inflatable boot of glass and copper with a broad rubber ring at the upper edge to shut off air. His purpose in using them, although not clear, was not for treating wounds.

The development of light transparent jackets removed the difficulties which at first we thought might be insurmountable and which forced us to use vasoconstrictor drugs alone to accomplish the desired constriction of the vessels.

From the work described in the article mentioned previously (1923)[12] and in subsequent published work carried out in France, we have shown clearly the influence of capillary constriction in preventing absorption of toxins from large burns or otherwise traumatized surfaces. The later work of Blalock on shock, proving that the escape of plasma from the capillaries and other small vessels into the traumatized tissues is of great importance in producing the symptoms in burns and extensive wounds, serves only to make more significant the use of the jackets which,

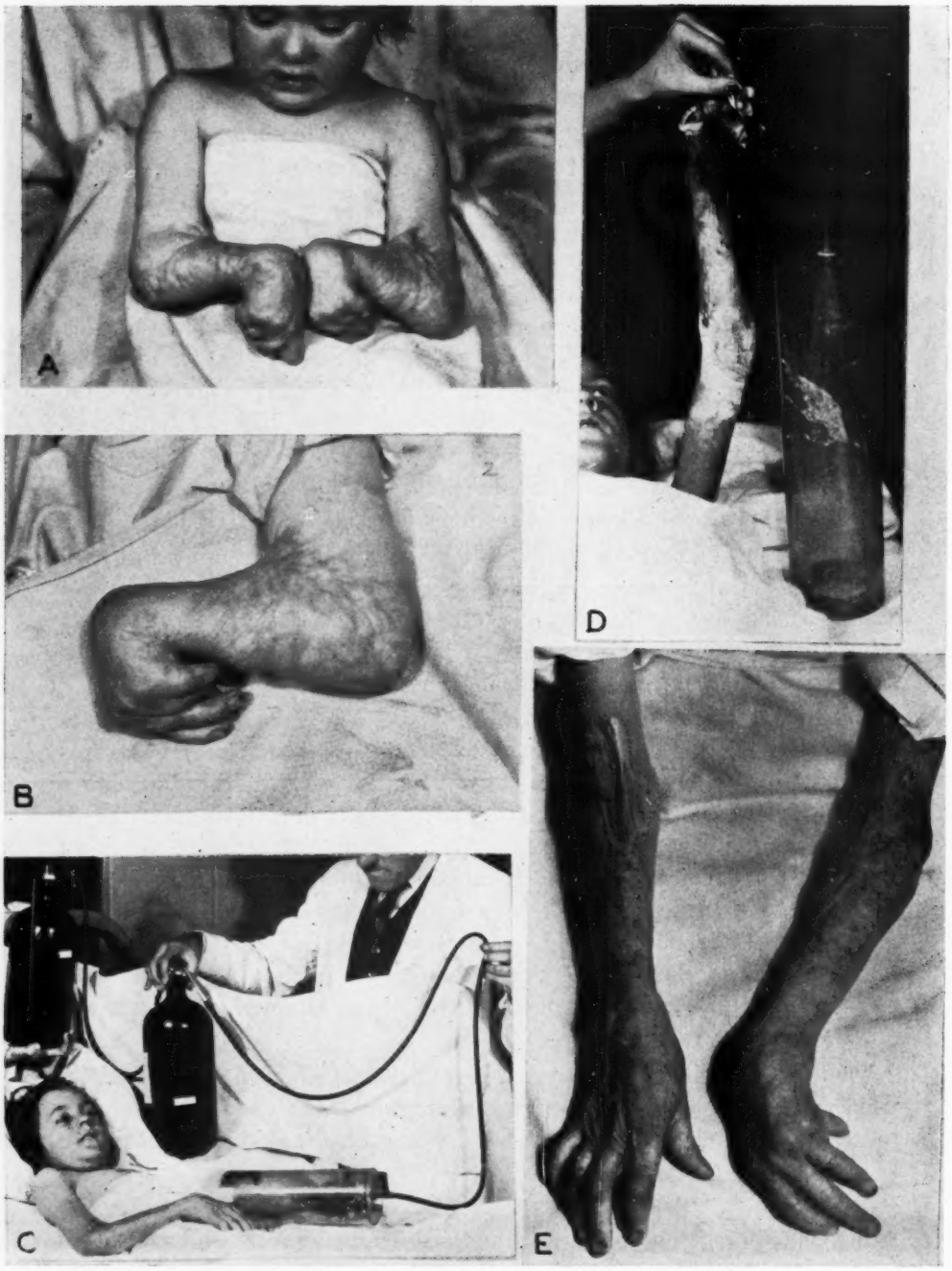


Fig. 3 (Case 1).—*A*, Deformity of joints of upper extremities. *B*, Degree of possible extension of left elbow before operation. *C*, Application of pressure within transparent jacket to skin graft of left hand. Head of air pressure represented by difference of levels of white marks on water bottles. *D*, Shows complete take of full-thickness graft on palm at time of removal of hand from jacket. *E*, Shows result of various operations for relief of contractions.

while protecting the surface, allow an even and easily regulated increase of pressure on the capillaries with or without the addition of vasoconstrictor drugs within them.

The difficulties and excessive cost of applying epinephrine in effective concentrations to large wounds due to evaporation and oxidation have been a stimulus to the development of the transparent jackets. The latter, in preventing oxidation and drying, makes epinephrine more efficacious in preventing exudation of plasma and absorption from the burned surface, the effects of both of which often prove fatal in large burns.

Another line of evidence that vasoconstriction accomplished by pressure or chemical action is advantageous is to be found in the effect of a pressure bandage such as elastic adhesive when applied to a wound. In a recent article[68] I have shown that this bandage usually rapidly reduces the number of microorganisms until sterility is reached.

I have shown still further in a second article[69] (with the help of Doctors Schrek and Avery) that an ulcer becomes sterile much more rapidly when covered with elastic adhesive directly without gauze than does a similar ulcer on the leg treated by boric acid solution and heat in the form of moist compresses. In this same report I point out that Halsted, in 1913, called attention to the advantages of maintaining moisture of the wound edges during healing in these words, "A moist scab, so-called, is better than a dry one. The surgeon has many opportunities to convince himself of this. . . . On covering the entire surface of the granulating wound with gutta-percha tissue the pain will be relieved and the inflammation subside."

"The dry scab imprisons secretion which in turn gives rise to tension and the tension impairs the vitality of tissues under and at the border of the dry scab to an extent sufficient to place them at a disadvantage with the microorganisms and to compel absorption of the toxins."

Another action of a dressing such as elastic adhesive which provides moist conditions was not specifically mentioned by Halsted. This is that by protecting the surface from recontamination or reinfection by outside organisms, the blood can locally build up at the wound antibodies definitely specific for the particular organisms present at first—in other words, the "pansement specifique" of the French. This is an aid to rapid sterilization and thus to rapid healing.

One disadvantage of a dressing which fails to maintain moist conditions on the wound surface is that drying puts the leucocytes out of commission and must also destroy antibodies. This is emphasized by Wright in a recent article.

So clear-cut and striking have been the results of elastic adhesive on old ulcers that we may say that antiseptics of any sort appear to be unnecessary and undesirable on them. This in simpler terms means that in the future wound treatment, except in the acute phase, will depend largely on physical rather than on chemical adjuncts or aids. In the

old ulcers in which elastic adhesive had been used, the plotting of the ideal curves of healing has shown that with this substance the curves of Carrel and his associates for the ideal healing of wounds must be revised when a substance even slightly toxic, such as Dakin's, is used during healing in place of a dressing with purely physical properties, such as elastic adhesive.

For a number of years in the clinic we have employed cellophane entirely surrounding a part over gauze as a species of jacket to hold moisture over a wound.

To summarize then, all the work of recent years on the treatment of wounds points definitely to two facts: First, to the advantage of employment of a system with infrequent dressings, sealed from the outside except for drainage and irrigation through controlled orifices; second, to the great advantage of the continuous or intermittent application of relatively slight degrees of pressure.

The transparent jacket or Theraseal system which I shall now describe for an attack on the problems mentioned is a logical development growing out of past methods employed. It is unique in that with it the very atmosphere surrounding the wound may be controlled at will. The part may be massaged at will through the jacket manually or by alternating positive and negative pressure therein. Sterile splints also may be applied directly or through the jacket. The total exudate may be collected at any time and studied. No other dressing affords these possibilities or conveniences, not to mention the sealing of the wound from air, which avoids pain and secondary contamination and allows direct application of pressure to skin grafts. Various lights including quartz and rare gas tube lights may be used to treat the wound through the jackets and photographs may be taken without removing them.

Since the terms airtight seal and occlusive dressing are used in describing the jacket system, I feel that a word of explanation is necessary to indicate what is implied by their use. Each jacket, whether of the thin transparent flexible fabric or of the thicker plastic tube variety, is, with rare exceptions, sealed hermetically to the part. But all of the jackets have as many inlets as desired in the form of tubes entering them for drainage and irrigation. Also, while in general the jackets are form-fitting, nevertheless a space exists between them and the surface which allows free and ample drainage from the wound. The exclusion of outside air avoids pain and secondary contamination but in no way impedes drainage or visibility.

DESCRIPTION OF APPARATUS

A better idea of the various forms of jackets which have been used through the years of their development, since 1935, may be obtained from the photographs than from any verbal description. (See Fig. 2, *A, B, C,* and *D.*) Rubber gloves and cylindrical tubing were at first

used. In burns of the trunk, transparent Cilkoid* was applied directly to the wounds in sheet form bound at the edges. Jackets were then made of real transparent rubber. In 1936, oiled silk was tried but was considered to be too yellowish in color and not completely transparent. During this year jackets were also made of pliofilm (Fig. 2*E*), a perfectly transparent, tough, very slow burning rubber composition material 0.0025 inches in thickness. These were fabricated into shapes desired with heat or cement. The inlet tubes were introduced and sealed to the material on a compression washer or were simply sealed directly to the jackets.

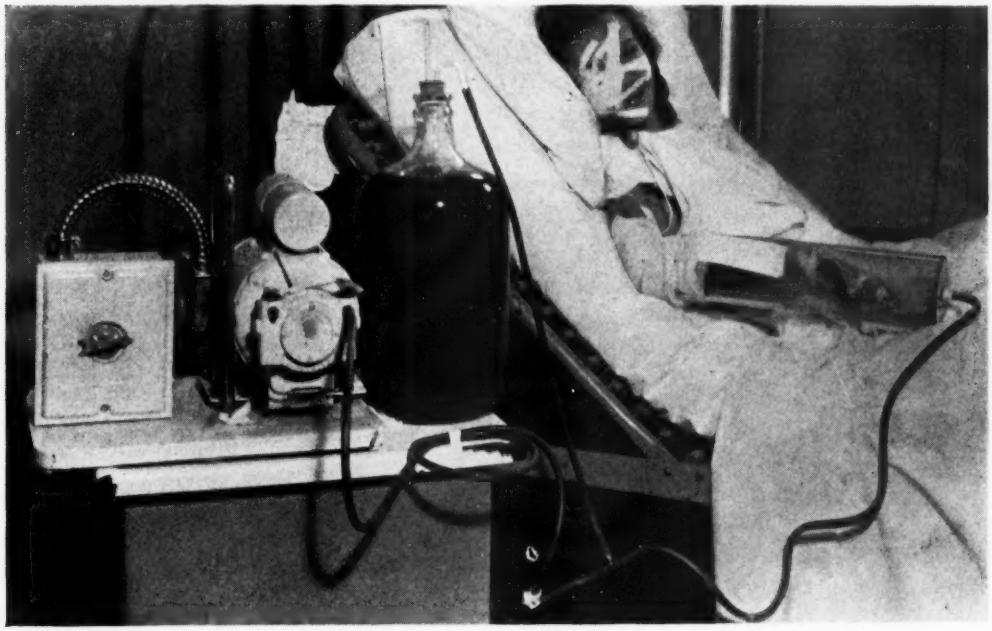


Fig. 4 (Case 3).—Showing skin graft of hand treated by constant pressure in transparent jacket. Pressure of 36 cm. of water delivered by pump and regulated by water gauge.

Description of Theraseal Jackets (Fig. 7).—In February, 1942, when the rubber shortage developed, we interested a firm in Chicago in fabrication of jackets of the new so-called miracle glass plastic cloth, krestex. These have airtight seams and will stand any pressures used in surgery without leakage. Openings are provided for an introduction of irrigation tubes which may be thrust through them or they may be ordered with flexible tubes built in. They are made in adult and child's sizes for arm, including hand; leg only; or leg, thigh, and foot; chest and trunk; short pants with zipper; and lastly, head cap with adjustable band for scalp wounds. They may be obtained in any special size or shape on order. All seams are watertight. Drawstrings are provided at the ends. The krestex material is elastic, wrinkleproof, very tough,

*Product of the Cilkoid Company, Marshalltown, Iowa.

and durable. While having a ground-glass surface, it is very transparent. Wounds are plainly visible when the jacket is held in contact with them; in fact, millimeters may easily be read on a celluloid rule through two layers of it. No acids, alkalies, or antiseptics used in surgery affect these jackets. They may be washed clean and sterilized by boiling, although soaking in bichloride of mercury 1:3000 for twenty minutes, followed by rinsing with saline solution is advised as a routine to preserve luster.

Only light oil, like sewing machine oils, will cause the jackets to deteriorate.

Semirigid Transparent Jackets for Extremities.—For purposes of applying constant or intermittent pressure to skin grafted surfaces on the upper and lower extremities, a slightly different type of apparatus has been developed. Transparent cylindrical tubing of cellulose acetate approximately $\frac{1}{16}$ inch in thickness and of various diameters, with one end closed by a flat or rounded head of the same material, has been made up into jackets for us by several different companies.* These tubes are light, durable, resistant to all antiseptics and to any temperature which is compatible with tissue viability. They will withstand far greater pressures than those ever employed for skin grafts. Plastic or metal tube connections may be seated in their walls by using the familiar arrangement of parts employed in seating a bicycle valve connection to a tube.

These tube jackets may be hermetically sealed to an extremity at a point above a wound by the type of seal shown in Fig. 6. In this a rubber cuff like that of a rubber glove, or larger, has its upper end slipped over the upper or corrugated end of the tube. The lower or thin end is then slipped over the extremity by holding it open until it seats gently at the desired level. Surgical lubricant is placed on the skin under the rubber cuff and a doughnut of rubber or gauze is inserted under the rigid end of the jacket. Three or four vertical strips of adhesive are placed from the skin to the jacket and a snug gauze bandage is applied over all. As pressure is raised within the chamber, a proportional amount will be exerted to press the seal against the arm, thus preventing leakage.

Application of Pressure to Skin Grafts.—When a low pressure is applied within the jackets, exudation is greatly reduced. In the case of noninfected skin grafts to which a constant pressure between 30, and 45 cm. of water was applied within the jackets, a total of only a few drops of sanguineous exudate was seen to be pressed out at the edge of the graft from the time of operation until healing had occured. I am lead by such findings to agree with Orr who, in speaking of infrequent dressings by his well-known method, says, ". . . . there is found to be usually less discharge (at long intervals) than is found at each dressing

*Hygienic Tube and Container Co., New York, N. Y.; American Hospital Supply Corp., Chicago, Ill.; Monsanto Chemical Co., Plastics Division, Springfield, Mass.

when they are changed frequently.'' Certainly the exudation is almost as little under optimum pressure conditions within the jacket as it would be in two clean wound surfaces held by stitches in proper appositional tension, if I may coin a term. The effect of this optimum pressure on the complete take and healing of skin grafts is beautiful to watch through the jackets.

Since we have found it easy by its use to maintain any degree of pressure on the small vessels under a skin graft or to alternate positive and negative pressures as desired, we have named this form of thin transparent semirigid jacket Thervator or *Ther*apeutic *va*scular regula*tor*. (See Figs. 3, 4, and 6.)

Application of Thin Transparent Jackets (Fig. 7).—By observing a few rules, the matter of applying jackets may be made very easy. If the jacket is to be used simply as a protective cover for a wet-soak dressing, which in itself is a great convenience, it is simply sterilized in bichloride 1:3000, slipped over the entire part and the drawstring tied snugly but not tightly. Irrigations are then made through the openings. When it is to be used directly in contact with the wound (method of choice), the skin is shaved and the wound cleansed or otherwise debrided. Skin and jacket are sterilized. Surgical lubricant is applied in a band two inches wide around the circumference slightly proximal to the point of contact with the upper edge of the jacket. The drawstring is tied. If intermittent irrigations are to be carried out, two small long rubber bands like those used around letters are slipped over the jacket and allowed to make slight pressure over the jacket and leg. These are spaced about one inch apart and the same distance below the drawstring. A few strips of one-inch adhesive running vertically from skin to jacket anteriorly, posteriorly, and laterally will prevent slipping. The circular rubber bands may be removed between irrigations.

If the pressure is to be applied constantly or continuous irrigations done, the jacket is similarly applied with the strips of adhesive but small bands 3/8 inch wide of thin Penrose drain material are fitted snugly over the jacket with light pressure, one inch and two inches, respectively, below the drawstring. Jelly lubricant or heavier zinc oxide ointment are placed under the edge of the jacket at the level of pressure by the rubber bands. Any excess material in the circumference of the jacket is folded on itself and the adhesive bands are stuck on as before to prevent them from slipping downward. A firm but not tight circular gauze bandage is applied over all. In our experience this type of seal has been completely satisfactory in preventing leakage. When removed, no pressure ring has resulted from the gentle pressure of the rubber band. Nevertheless, the position of the bands should be changed from time to time.

The other type of seal by infolding a rubber cuff is also very simple and will hold air indefinitely. It has been described fully under the

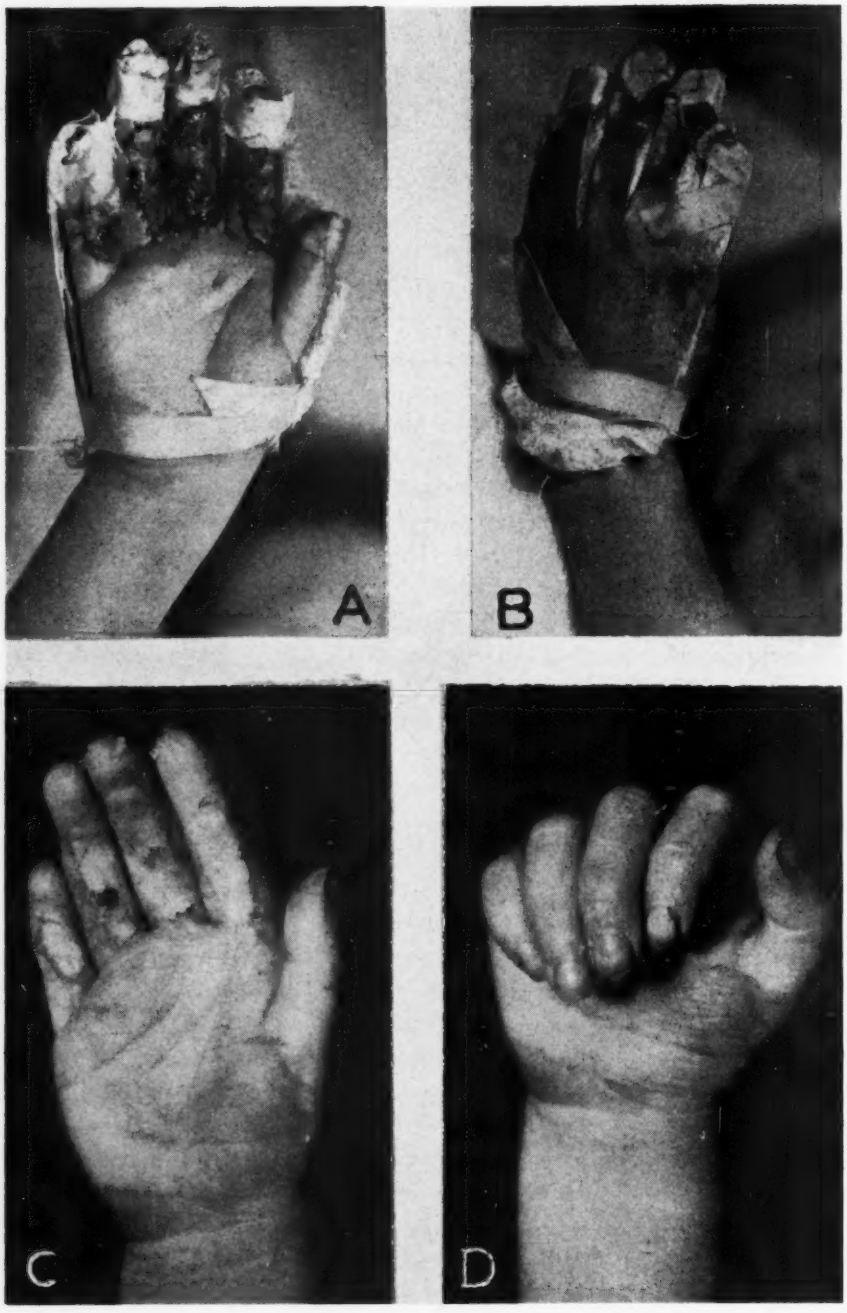


Fig. 5.—Result of skin grafting for flexion deformity on patient in Case 5. Grafts treated by pressure in jacket without other dressing. *A*, Full-thickness grafts four days after operation. *B*, Light posterior aluminum splint for fixation of fingers. *C*, Condition of grafts sixteen days after operation showing degree of extension possible. *D*, Degree of flexion possible on same day.

semirigid cylinder jackets. (See Fig. 6.) Instead of the edge of the glove cuff, the drawstring edge of the Theraseal jacket is inverted by tying it and placing the usual circular band of light Penrose drain material around the jacket proximal to it, or by simply threading the rubber band through the drawstring slot. The outer part of the jacket is then pulled upward to invert it over the drawstring portion for about one inch. The usual adhesive bands and a snug but not tight roller gauze bandage complete the application.

Advantages of Jackets from Standpoint of Treatment.—Since the very atmosphere surrounding a wound may be regulated at will in the jackets, any form of therapy may be efficiently carried out. In fact, we would greatly prefer not to lay down any stereotyped routines. The hermetic closure and covering provided serve many useful purposes. The patient may turn himself frequently in bed, thus preventing the development of contractures and decubitus ulcers. The jackets take the place of tannic acid or other coagulated membranes and keep outside air and contamination away. They provide for drainage which is disposed of by periodic emptying. At all times active and passive movements may be carried out in joints of the extremities, especially of the hands. If splinting is necessary, lightweight splints may be applied within or outside of them. Once in place and sealed, one may order Dakin's, azochloramide, or other solutions as irrigations at four-hour intervals or as desired. The jackets may be completely filled with saline or other solutions and a constant flow established by the well-known drip method. Temperatures may be varied at will. Irrigations may be alternated with drying by the passage of warm, dry filtered air through the vents. Filtered air first passed over an electric hair dryer for warming may be pumped through the jackets. The jackets may be filled with oxygen or other gases under any pressure desired. Quartz light therapy may be carried out through the jackets without their removal. The advantage of visibility is very great in the case of decubitus or any other complication. We have had pressure sores, present before application of the jackets, heal within them. The hermetic sealing provided by the jackets avoids offensive wound odors and prevents cross contamination of wounds.

Irrigations are easily carried out by partially filling the jackets with the desired solutions or by moving of Carrel or other tubes sealed through the vents over the wounded surfaces while a given quantity of solution passes through them. The patient is then turned in various positions in the next few minutes so that every portion of the wound is exposed to the action of this solution, after which it is allowed to drain through the lowest vent. If desired, the total exudate may be collected and kept for study. The effect of hypertonic tubs may be obtained without removing the patient from the bed and without leakage.

We have mentioned the use of low concentration of epinephrine solution within the jackets early in burns. Whatever solution is used, none is

lost and the action continues until it is emptied or oxidized by the wound or air within the jacket.

We have found Dakin's solution useful in getting sloughs separated. These are dissolved and expelled through the vents.

Since no other dressings are used on the wound and the jackets may be resterilized after use and used several times on the same or different patients, their use is very economical.

The Army Bulletin[5] gives the report of the Committee on Surgery of the National Research Council, which has investigated many different forms of burn therapy. This gives the transparent jacket method as an "alternative method of treating infected burns of the extremity." Irrigations are advised within the jackets, of 0.2 per cent sulfanilamide in physiologic saline solution. J. A. Sinclair suggests that Ringer's solution be substituted for saline on account of its calcium content. The Committee suggests the drying of wounds between irrigations by the passage of warm filtered air through the jackets.

Studies of Wound Exudates.—The total exudate collected daily has in general shown a progressive reduction in amount and a progressive thickening or increase in specific gravity as infection clears up. These findings are similar to those for exudates from acute pleural empyema cavities. Although organisms may be present in fairly large quantities, they seem to inhibit each other's pathogenicity and activity. The possibility of the presence of bacteriophage must be kept in mind. Phagocytosis is very active since many intracellular organisms are seen in the smears.

At the time of this communication we are treating a man who has both legs burned from mid-thigh to ankles in two transparent Theraseal jackets. (See Fig. 7.) He is having intermittent irrigations with 2.5 per cent Dakin's solution through the vents in the jackets. He is very comfortable and able to move around frequently in bed. The bed is dry. Grafting will be accomplished much sooner than if coagulation methods, such as tannic acid, had been used.

Because of the many different forms of therapy which can easily be carried out aseptically on wounds by the use of these jackets, I have named them Theraseal jackets* or *thera*peutic *seal*.

A few typical cases which serve to illustrate the development and use of the transparent jackets are reported in detail.

CASE REPORTS

CASE 1.—M. A. M., a 2-year-old infant, was admitted Jan. 27, 1933, with a history of a scald of both elbows, forearms, and hands when she fell forward into a kettle of boiling lye soap. Before admission treatment consisted of tannic acid, therefore on admission the areas described were very largely still covered with black

*These jackets are manufactured by and may be obtained from Petra Mfg. Co., 663-71 Washington Blvd., Chicago, Ill.

tanned membrane. Many pockets of pus were found under the crust, therefore the greater part of it had to be removed. On healing after pinch grafting in several stages, the condition was as seen in Figs. 3, *A* and *B*, Dec. 14, 1933, with the elbow joints, wrist joints, palms, and fingers all drawn up in extreme flexion contraction. Several plastic operations were required to correct all of these contractures.

At operation, Dec. 16, 1933, the contracted cicatrix of the left elbow was excised and a full-thickness skin graft substituted.

Jan. 16, 1934, the cicatrix of the right elbow which produced flexion was lengthened and the contracture relieved by a "staggered Z" plastic operation.

Oct. 15, 1935, the contracture of the left wrist was relieved by dissection and the application of a thick split graft from the thigh.

Oct. 21, 1935, the contracture of the right wrist was treated by excision and application of a thick split graft from the left thigh.

Since this report deals with the application of pressure to grafts by placing the extremity in jackets, the palmar and finger contractures will be reported in greater detail.

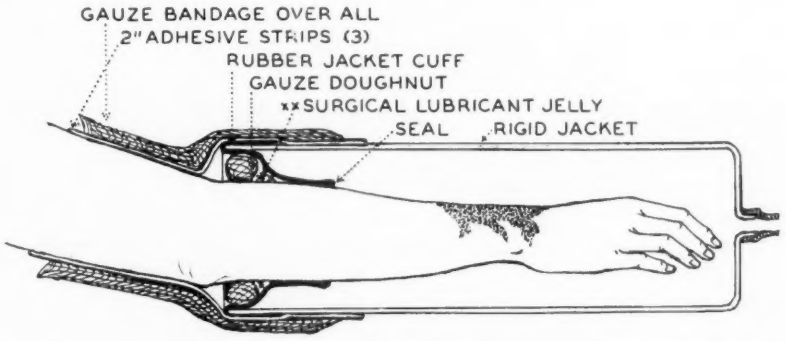


Fig. 6.—Semidiagrammatic drawing showing arrangement of hermetic seal for semirigid transparent jacket used over skin grafts. For complete description see text.

At operation, Dec. 5, 1935, the scar of the right palm which bound down the fingers in flexion was removed by mass dissection. A pattern was made after all fingers had been fully separated and extended. The pattern was divided into two parts and two corresponding full-thickness grafts were removed from separate abdominal areas, the latter having the skin edges undermined and closed. The two grafts were sewed together in the shape of the pattern and were sutured with a continuous suture of silkworm gut at the edges. A hermetically sealed pressure jacket consisting of an ordinary No. 8 surgical rubber glove was slipped over the hand (see Fig. 1 *D*) and a seal made at the wrist by applying heavy zinc oxide and wrapping a band of rubber, consisting of a small rubber Penrose drain split in half (lengthwise), around the wrist over the glove cuff with just enough pressure to maintain contact of the cuff outside of the zinc oxide. A small glass tube was tied into one of the fingers of the glove and the glove inflated to a pressure of 20 cm. of water at which point it was maintained by water bottles. The pressure was maintained for fifteen days. The graft took, almost in its entirety. A few small areas at the edges sloughed but these rapidly healed in. The webbing of the hand and palm appeared to be relieved.

Jan. 2, 1935, by a circumscribing incision the dense scar tissue of the palm, thumb, and fingers was removed and the contraction relieved. The denuded area was covered by full-thickness grafts cut in a manner similar to that employed on

the other hand. A glove was employed for positive pressure like that used on the other hand. Except for a small area on the thumb, the graft took. The palmar surface of the hand was covered and the fingers well-separated by the graft.

Feb. 11, 1936, two staggered Z plastic operations were employed to lengthen the scar bands holding the right palm and wrist respectively.

April 3, 1936, the flexion deformity of the left wrist was relieved by dividing the scar and swinging a flap from the dorsum of the wrist anteriorly. A few small deep grafts sufficed to complete the closure of the area from which the flap had been swung. The right palm was dissected free of scar which had remained after previous procedures and a small full-thickness graft cut from the thigh was transplanted to it.

On June 2, 1939, a note was made when the patient returned for observation that there were moderate contractures of the left fourth and fifth fingers and a slight residual contracture of the left wrist. All other regions, at this time, had responded nicely to grafting, and the patient had excellent function of her hands, wrists, and elbows.

At operation Nov. 4, 1939, the left palm was opened and the contracture of the fourth and fifth fingers relieved by excision of the dense scar from them. A full-thickness graft was patterned to fit the defect and dissected from the upper abdomen. It was sutured into the palmar raw area with dermal silkworm. The hand was placed in a transparent cylinder of cellulose acetate with a rubber glove cuff above the elbow in order to hold constant pressure on the arm while keeping it free of all other dressings (Fig. 3 *C*). The air pressure was maintained at 20 cm. of water within the chamber for four days (Fig. 3*D*). The graft was entirely viable at the end of this time. A dressing of lambskin with wool attached was applied over dry gauze. This was continued during the next three weeks.

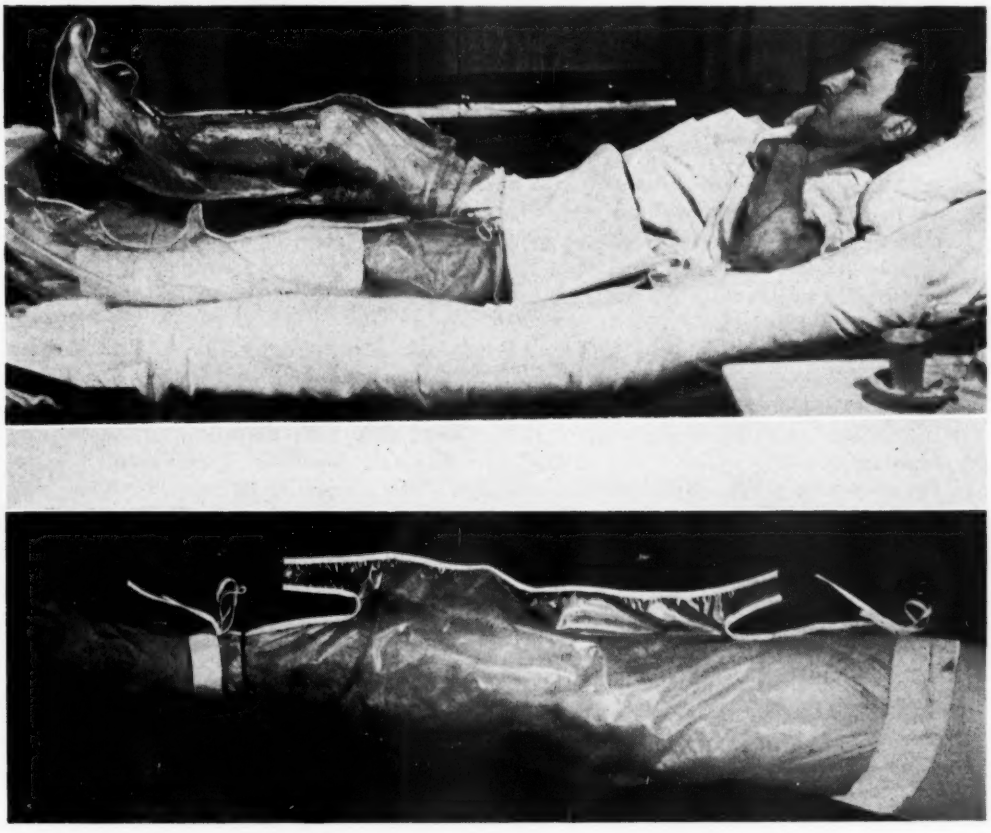
The graft was a "take" in its entirety. The final photograph shows the condition of the upper extremities as compared with their condition before plastic work (Fig. 3*E*).

CASE 2.—M. K., a white boy, aged 14 years, was burned six days before admission, Nov. 30, 1935, when a can of burning gasoline was kicked over and set the clothes on his right leg on fire. Examination on admission revealed a complete loss of skin from the perineal level of the right thigh to the lower ankle region (Fig. 2*B*). Dirty necrotic skin and white necrotic subcutaneous tissue comprised the burned area and much foul purulent exudate was present over its surface. Physical examination, except for enlarged cryptic tonsils, was essentially negative.

Treatment and Course From Nov. 30 to Dec. 11, 1935.—Before being admitted to this service the patient was treated by immersion, two to four hours, morning and afternoon, in warm saline solution in a bathtub, alternating with exposure of the wound to air in a lighted cradle. During this time his temperature was septic in type after the first four days, reaching 102° F. daily. Necrotic skin was débrided from the leg on Dec. 7. On Dec. 11, a sterile rubber tube was slipped over the entire wound of the leg and pinched off hermetically below the foot and likewise sealed above the wound on the thigh (see Fig. 2*A*). This appeared to give much relief to the patient from local pain. The temperature became only slightly higher each day, due probably to insulation, but the white blood cell count diminished. The wound exudate which collected inside the jacket gradually diminished in amount and the wound, which could be observed through a threaded cap, grew progressively cleaner. Oxygen was used under slight pressure to inflate the jacket. By Jan. 2, 1936, the exudate was less in quantity (only about 300 c.c. daily) and the specific gravity was less. The jacket was temporarily removed and a thick split-skin graft, 60 square inches (12 by 5) cut with the Blair knife and chamber, was sutured to the entire popliteal space and lateral and medial surfaces of the knee. The jacket was then readjusted and air pressure of about 42 cm. of water, gauged by

water bottles, was applied to inflate the jacket. The exudate first increased to 1100 c.c. after the operation, but rapidly decreased thereafter to between 150 and 200 c.c. daily. The graft became firmly united over all of its bed except for small areas near the patella (Fig. 2*C*). The jacket was removed after fourteen days and the remainder of the leg grafted with many small deep or pinch grafts in several stages. Although the patient was emaciated, his general condition was improved by frequent blood transfusions. His leg was entirely healed on discharge, April 14. He was subsequently followed as an ambulatory patient in the outpatient department after discharge.

A.



B.

Fig. 7.—*A*, Treatment of granulating wounds of both thighs and both legs within transparent jackets. Note vents at top of jackets with tube connections in place on right and vent at heel for drainage. Jacket on left leg is used to cover dressing and provide moist compress. That on right is used with hermetic seal for direct irrigation without any other dressing. Note transparency. *B*, Transparent sleeve jacket for leg and thigh with foot excluded. Note vents and seals above and below. (Photos by Tommy S. Gibson.)

CASE 3.—D. M. B. a 12-year-old girl, had her right cheek and right hand burned at 9 months of age when she fell into an open grate. The healing was slow and the cicatrices in both areas caused contraction. On examination an otherwise essentially normal child presented a contracture of the entire right cheek which caused an ectropion of the right lower eyelid and a turning up of the right upper lip. The right fifth finger was bound by a scar web on the palmar side in right-angled flexion, the tip of the finger nearly touching the palm.

Treatment.—The scar on the cheek was excised Nov. 29, 1941, and a thick split graft substituted. A separate operation was contemplated for the relief of the contraction. The scar bridle was excised from the right fifth finger under gas-oxygen-ether anesthesia on Dec. 5, 1941, and a full thickness graft from the abdomen was sutured into the raw surface on the finger. A small aluminum dorsal extension splint was applied to the finger. The entire forearm and hand were placed in a transparent positive pressure chamber of cellulose acetate sealed to the forearm by a glove cuff near the elbow. A slow-speed air pump was employed to maintain a constant pressure of 36 cm. of water by gauge. (See Fig. 4.)

It is interesting and revealing to note that under direct vision through the jacket the graft, except for two small white areas, was all pink at the end of approximately eight hours. These two areas were also pink the next morning (about fourteen hours later). The jacket was comfortable, permitted free turning and movement within it, and remained sealed throughout. Good function resulted.

Case 4.—G. E. L., Jr., a 24-year-old junior medical student, entered Vanderbilt Hospital on July 5, 1939, for the operative correction of a deformity of his left hand. This followed a burn at the age of 6 when he fell with his hand extended on a hot stove. He was treated with vaseline gauze at the time and no splint was applied. A flexion contracture resulted. At the time of examination there were hard cicatrices at the bases of the second, third, and fourth fingers, as well as on their palmar surfaces. The scars caused marked flexion of the index finger, the tip almost touching the palm, and moderate flexion of the third and fourth fingers. Although there was considerable atrophy of the small muscles of the fingers, the flexor tendons and sheaths did not appear to be damaged. The distal phalanges could be flexed. Except for a limitation of flexion of the right knee, from an old osteomyelitis, the physical was otherwise negative.

Treatment.—At operation, July 6, 1939, almost all the dense scar was removed from the second and third fingers and palm by sharp dissection under novocain. The fingers were then rather forcibly extended without material damage to tendon sheaths or arteries. The raw areas were then traced and whole-thickness skin grafts were cut from the right upper arm. The edges of the donor wounds were undermined and sutured. The grafts were sutured at the edges and a few stitches used also to hold them in contact with their bases on the fingers. A posterior extension splint of light aluminum was applied with adhesive to the fingers and hand.

A positive pressure chamber of transparent cellulose acetate was slipped over the hand and forearm. Employing a rubber glove cuff, a hermetic seal was formed near the elbow. By means of a water bottle gauge, air pressure at 42 cm. of water was kept on the skin of the forearm and graft. This was maintained for ninety-six hours, at which time the graft was entirely viable. The patient then had a lamb's wool pressure dressing applied to the graft. The skin of the grafted areas subsequently took nicely and the patient regained excellent function of his finger. On the index finger a small trophis ulcer formed near the nail. This was excised and grafted with two small deep grafts. Healing was prompt and has been stable for four years.

Case 5.—E. N., a white girl of 4 years, gave a history on admission of an electrical burn to her right hand received two weeks before. This was caused when, following a windstorm, she grasped an electric high tension wire which had fallen in her schoolyard, burning the palmar surfaces of the second, third, fourth, and fifth fingers of the right hand. Granulating wounds were present in the areas described as follows: A large wound was found involving most of the palm of the hand and extending on through the palmar surfaces of all the fingers and the web between the right first and second fingers. With hot soaks of saline solution, followed in a few days by Dakin's solution irrigations, the wounds healed except for small granulating areas on the palmar surfaces of the second and third fingers. Two

months later the patient was readmitted on Nov. 7 with marked flexion contractures of the second, third, fourth, and fifth fingers, most marked at the proximal interphalangeal joints. All except the latter were drawn down to a right angle. The latter was held in flexion to within 15 to 20 degrees of complete extension.

At operation, Nov. 11, 1938, the scars from the four fingers of the right hand were excised from their palmar surfaces. Four whole-thickness grafts were cut by pattern from the anterolateral surface of the right upper thigh. The edges of the wounds at the donor sites were undermined and easily closed with mattress sutures. The grafts were fitted and sutured into the wounds of the fingers. The tendon sheaths were left intact. A small thin aluminum splint shaped to the individual fingers was strapped to the dorsal surfaces of the fingers and to the hand with sterile adhesive to hold the fingers extended. (See Fig. 5.) Without any further dressing the whole hand and forearm were placed in a positive pressure cylinder of cellulose acetate with a cylindrical glove cuff between the upper forearm and the jacket to make it airtight. A pressure of 25 to 30 mm. of water, regulated by water bottles (see Fig. 5), was kept constantly applied.

The following notes are taken directly from the hospital record: "Under direct vision the take of the grafts is evidenced by a progressive change from white to pink observed as follows: The fifth finger graft was definitely pink five and a half hours after operation. A portion of the graft of the third finger was pink ten and a half hours after operation. The grafts were not observed during the night after 11 P.M., but by the next morning (twenty-one hours after operation) the grafts of the second and fourth fingers had become pink for the most part and twenty-five hours after operation they were pink throughout."

In three days' time the grafts were definitely viable as evidenced by their livid pink color. No blistering was present. A little boric acid ointment was applied and lambskin with the wool attached was cut to shape and applied with slight pressure over gauze to the grafts. The splint was left on and bandaged in. The grafts all took nicely. (See Fig. 5*A*.) In twenty days the patient could fully extend and flex the fingers. The patient's hand was examined several weeks after grafting and function of the fingers was found to be normal.

The rubber glove-cuff seal which was employed held the pressure with insignificant leakage. The 30 cm. head of water in the upper bottle only needed restoring at twelve-hour intervals. Ordinary lubricant jelly such as is commonly employed in hospital wards was applied to the upper forearm before application of the jacket to improve the seal.

The hand and forearm were comfortable at all times, and the latter, after many days, showed no pressure ring at the point of contact of the airtight glove-cuff seal.

CONCLUSIONS

Evidence presented appears to warrant the following conclusions:

1. Extensive burns in addition to causing early primary shock also may produce early circulatory changes and physical and chemical alterations in the blood from plasma loss and surface absorption.

2. The systemic and local treatment in burns should, therefore, be considered an emergency of the first order to be carried out as soon as the patient's condition permits.

3. The patient's general condition should be treated by appropriate measures in each stage following the principles and indications outlined.

4. In the treatment of his wound, avoidance of contamination and prevention of plasma loss and of surface absorption are of paramount importance.

5. In accomplishing these aims from the start, strict asepsis, an efficient cover infrequently changed, and a certain amount of mechanical pressure or pressor drug action on the part are of aid.

6. The transparent wound jackets described are of definite use in carrying out these aims.

7. They are of definite value in preparing the surface for early grafting and for applying regulated pressure to grafts and the tissues underlying them.

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EARLY TREATMENT OF BURNS

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BURNS, either alone or in combination with other injuries, are a frequent cause of casualties, both for civilians and members of the Armed Forces, during the present war. As most individuals thus injured live, mortality rates do not give a true picture of the economic loss. The price of prolonged hospitalization, suffering, disability, disfigurement, and mental upset is enormous. Members of the medical profession now in the armed services, who in ordinary circumstances would have referred serious cases to those particularly interested in this subject, now must undertake their management alone. This problem would not have been difficult if a burn were an entity like many other conditions. On the contrary, it requires knowledge of the treatment of a peculiar type of large wound. It is made doubly difficult by being a wound which is extremely painful, usually has copious exudate, is accompanied by much edema in adjacent tissues, is easily contaminated, and which cannot be closed immediately unless small. If treated kindly, it will close itself quickly by the natural healing processes, when the injury has been superficial. If deep, delayed closure takes place by healing from the sides of an ulcer with contracture and scar epithelium, or by skin grafting. The early treatment has many controversial aspects about which there is no general agreement.

The Problem.—It is not the purpose of this communication to discuss the relative merits of innumerable agents and methods used in local treatment. One method known to be good will be discussed and described. This decision was made because there is need to urge one form of local treatment which is so simple that it can be understood and put into reasonably good practice by those who, having never treated a severe burn previously, are now faced with the possibility at home, and the probability in battle areas, of having to care for many such casualties. The members of the profession who treated large numbers of burns in peacetime were few. Suddenly it has become necessary that many be prepared to do so. The multitude of materials, and the methods for their application, which have been advised (and to which there is constant addition), has served to confuse the uninitiated who are to be the all-important vehicles for carrying early treatment to the patient. This is particularly so in the Armed Services. Those who have special knowledge and facilities should undoubtedly continue with investiga-

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tion of the burn problem in all its aspects. One part of this is the finding of better materials and methods for local therapy.

The subject of burn treatment may be divided into that designed for prevention and that designed for cure. That "prevention is better than cure," is most true when it is applied to burns. Much remains to be done on this aspect of treatment which is not within the scope of this communication. Therapy designed for cure is divided into early, intermediate, and late. The early treatment may be said to have ended when the first week has passed. This time is chosen because then the initial phases of primary and secondary shock have elapsed. The liver and kidneys are beginning to show evidences of recovery from the toxic state.[1] The average time of death in our cases in recent years has been about five days (excluding deaths later than ten days after the accident).[2] This article will discuss early treatment under the heading of local and general thearpy. It is not intended that anything original be introduced. The material presented represents opinions formed as the result of experience with many burns in children and adults in civilian and service practice.

Topical Application.—The question of local application, being the most controversial, is discussed first. In choosing a material for service use, simplicity must rule. It is better if it is the same for first aid and definitive therapy. Whatever is chosen should be available in large supply, easily packaged for continued sterility and handiness in use, and capable of withstanding wide variations in temperature without change in composition or texture on return to ordinary operating conditions. Its use should be easy for nonmedical personnel and untrained medical personnel. It should not be harmful to already damaged tissue cells. The latter is one of the controversial points. Except in a gross manner, it is difficult to know what materials are injurious when applied directly to the exposed epithelial cell elements remaining in the dermis. The healing processes are undoubtedly affected by the local application, but controls are difficult to arrange, and the assessment of results to the satisfaction of everyone is practically impossible. The presence of infection, maceration, and chemical irritation or necrosis are the most obvious causes of damage to epithelial cells during the course of treatment. They are likely of greatest importance in the order named. The combination with the material used for local application of bactericidals or bacteriostatics would appear to be a sound principle as long as these substances do no direct damage to the remaining dermal epithelial cells, or the course of repair. The latter includes the separation and removal of dead tissue, and the recovering process. The details of how this takes place, and what retards or expedites it, are so little understood that it is useless to wait for decisions on controversial points to determine what should be urged presently for local application. Time will bring the answers to many questions, but that

does not help those whose problems are urgent today. This pertains particularly to those in the Armed Services unskilled in the management of burns. They must be given simple directives to the query, "What is the best method of handling the burned area?" That which constitutes the "best" must at most represent an opinion with which many may not concur. Thus a "good" method as viewed by present-day standards, and one which uses a material for local application which satisfies reasonably well the desirable features mentioned above, is a cream, jelly, or ointment *occlusive pressure dressing method* such as described by Koch,[3] Ackman and Wilson,[4] and others.

Consideration of a Cream, Jelly, or Ointment.—The perfect material for local application has yet to be found. There are so many qualities that are expected of it that the likelihood of combining them in one material is remote. The search has received most decided impetus since the commencement of the war. The comparison of materials is difficult owing to the varied depths of burns, unknown factors affecting healing, the myriad permutations and combinations of differences in age, sex, race, nutrition, hormonal activity, etc., which make one individual different from another. Many substances have had extravagant claims made on their behalf, such as vitamins and hormones in mixtures. There is lacking anything approaching conclusive evidence of their value. The "kindliness" with which some donor areas heal after removal of "calibrated" skin grafts, when compared to other parts of the same area treated differently, is fair proof of the undesirable qualities of some forms of surface application.

The advantages of an ointment, cream, or jelly are many. Those of particular importance are listed.

1. It is easy to apply by medical and nonmedical personnel.
2. It needs no elaborate paraphernalia in its employment.
3. It can be packaged in a sterile fashion in suitable containers.
4. It can be combined with gauze mesh in the original packaging. This eliminates one maneuver in the primary dressing.
5. Depending on the medicaments in it, it can be made available in large supply.
6. Ointments can be made, which after wide variations in temperature, return to the original composition and texture.[5]
7. It can be applied quickly—time does not have to be allowed for drying as in the case of escharotics and plastic materials.
8. A repeat application is not necessary. The first-aid treatment can, if circumstances demand, become the definitive treatment.
9. Nursing care necessary is at a minimum.

All of these points are most advantageous in service practice. Indeed, they are in certain situations "all important."

Ointments vary much and that which is an advantage in one is a disadvantage in another. A water miscible base would appear to have

some advantages, if the material for local application were to be changed to another whose action was disturbed by the presence of oil. If the original material were continued to the skin grafting stage it would be necessary to switch from the oil containing ointment. However, this is a minor matter as the patient is by that time probably in a hospital where such changes are not difficult. Obviously, there is much to be learned concerning the bases from which ointments are made and their effects on the repair processes. That infection and maceration are harmful has already been stated. Skin surfaces may have epithelial cells injured by the steeping which takes place when a dressing is used which prevents the escape of moisture. This is prone to take place under vaseline, but less so if it is combined with other medicaments. Thus, borated vaseline seems less macerating. Water miscible creams and jellies are less likely to cause it.

Contamination and Infection.—The problem of infection is best managed by prevention of initial contamination rather than by bringing it under control later. This prevention may be impossible due to circumstances, such as the nature of the injury, and the time between the accident and satisfactory therapy. Infection means the invasion of the tissues of the body by living pathogenic organisms in such a way as to favor their growth and permit their toxins to injure. Thus, there is often contamination without the condition progressing to an infection of any significance, despite the fact that this large open wound has some partially cooked tissue as its base, or later has granulation tissue. Infection in our experience has not been a great producer of morbidity or mortality. That contamination can be completely removed or infection can be controlled by surface applications of medicament is controversial. The type of medicament, the amount and type of contamination, and the quantity of necrotic tissue present would appear to be important factors. Sulfonamides have been of help. Other bacteriostatics and bactericidals of more ancient use are also of value. There has been some tendency to put them aside. That sulfonamides represent only a phase in the search for better materials is forecast by reports of penicillin as published.[6] While sulfonamides are far from ideal, their known value at present is sufficient to cause their inclusion in any ointment which is chosen, until other compounds have been well tried and found more satisfactory by those who have proper skill and facilities. The adsorption from a large open wound such as a burn of second degree is so rapid that care must be taken not to employ a very soluble sulfonamide directly on the surface, or to incorporate it in an ointment from which it is not too quickly removed. Under such circumstances the toxic effect of the drug is an added insult to an already sick patient. Local concentration can be maintained for many days if sulfathiazole is incorporated as recommended by Ackman and Wilson.[7]

The Application.—When an ointment or cream is put on a burned surface it should spread easily and adhere to that surface. This is a quality not possessed by some unguents. This factor can be circumvented by applying them directly to the gauze, and thence to the body surface. It is even better if the material is parceled in such a fashion that this maneuver is not necessary, the ointment being impregnated in gauze and packed so that a small part may be used without gross contamination of the whole bundle.

The gauze may be of wide or close mesh. The former is preferable as it carries much ointment and allows drainage into supporting dressings. When granulation tissue forms the surface, the gauze should be finer as the granulations tend to grow through the coarse variety if it remains on for some time. The chief difference between this and *tulle gras* is in the material (ointment or cream or jelly) used with the gauze.

The local application should overlap considerably the limits of the burned area. It is padded by sterile fluffed gauze or machinist's waste. Firm bandaging with pressure reinforced by adhesive plaster fixes the dressing. The type of bandage used by us has been flannelette cut on the bias. This has some stretch so that pressure can be applied and maintained for some time. Elastic bandages or elastic adhesive rolls are satisfactory. Enough padding is used to absorb considerable exudate. More is necessary with superficial than with deep burns as the latter do not "weep" so much. The pressure is designed to check the "bleeding" of the plasma into the tissues adjacent to the surface lesion. Thus the local edema is largely controlled. If this pressure dressing is removed at any time during the first few days after the accident, swelling will take place.

The padding, and bandaging, and fixing of the dressing represent the most difficult part of this form of treatment. The supply factor (of padding and suitable bandages) is a disadvantage in service practice, but is not a great problem in civil establishments. It requires practice for medical personnel to put a satisfactory dressing of this type on hands or face where many of the burns occur. Nonmedical personnel would need much instruction and practice. Cleansing and débridement, local application, and the pressure dressing being three distinct steps in the therapy of the local lesion, the first and last may have to be neglected, from force of circumstance. The pressure bandage should be applied as soon as possible, and thus nonmedical personnel should be taught its use. Cleansing and débridement are closely similar to a surgical operation in that they need sterile supplies and sterile technique as well as a plan of action to produce the appropriate effect. Thus, first-aid therapy includes an ointment or cream in gauze application, next to the burned surface, overlaid by some padding, the whole being fixed by a pressure bandage and adhesive plaster. The first-aid therapy

should be continued as the definitive treatment if much time has elapsed between the two, no débridement being considered advisable.

Too much emphasis cannot be placed on the prevention of contamination. Treating the burn as a large open wound if circumstances permit is most important. All the usual surgical precautions concerning sterility are urged—sterile gowns, gloves, drapes, instruments, and the masking of the patient and all who are near. If circumstances permit segregation of patients, burns should be in a ward apart from patients with infections. The local application, if and when it represents the definitive local treatment, should not be removed for at least a week unless circumstances warrant a change. The constant change of dressings does no good, and often does harm.

Cleansing and Débridement.—Controversy arises from the fact that the value of a débridement in this type of wound is not agreed upon by all. Certainly in many cases treated by us without débridement the results have been generally satisfactory. However, it is our opinion that débridement should not be abandoned by the casual treater of burns, until more evidence accumulates to support this contention. If there is no supply of sterile water, soap, or detergents, no method of controlling pain during the procedure, or much time has elapsed between the accident and the first treatment, the circumstances might justify its omission. This step in the treatment has been accomplished in our work by flooding the part with sterile water or saline solution. Cultures of the soap solution distributed by the pharmacy at our hospital resulted in the growth of a variety of organisms. Thus, a sterile solution of a soft soap is used. Benzine may be used at this stage to remove oil or grease. The débridement consists in removal of any portion of the skin that is loose or raised in blebs. This is done rapidly, using wet gauze as a "wipe." In the average case (less than 10 per cent of the body surface affected) it should not take more than two or three minutes. It may be necessary to scrub with a brush a burned area into which foreign particles have been driven. There must be some definite reason present for such therapy because it is associated with considerable direct trauma to the surface. The area is dabbed dry with a towel and the local application applied.

GENERAL THERAPY

Control of Pain.—While control of pain is primary in the mind of the patient, it cannot be carried out satisfactorily if there are no medical personnel present. Thus, the question of local application was dealt with first. Pain is controlled by intravenous morphine; ⅛ gr. intravenously and a similar amount hypodermically by withdrawal of the needle is an average initial dose for adults. The intravenous portion is administered slowly. If medical personnel are not present and morphine is available it may be given (¼ gr.) by mouth but the delay in action is

so great, that if medical personnel can be reached within one-half hour it is better to give nothing. A general anesthetic is rarely necessary. Many burns are associated with damage to the respiratory tract by fumes or superheated air. Chest complications may occur rapidly. A general anesthetic is a complicating factor and should be particularly avoided in this type of case.

General Supportive Measures.—While primary or neurogenic shock may be seen, it has not been a factor in our cases. Lying down, with freedom from disturbance and maintenance of body warmth, should bring it under control quickly.

Happily, the subject of this article does not permit a discussion of what is meant by secondary shock or its signs and symptoms. Its treatment in burns of moderate or severe degree should start long before it can be seen clinically by ordinary observation. That is the first factor to recognize. The second is that it should be adequate. Whole blood, concentrated serum, normal serum, and plasma have been used by us in this phase. The viscosity of the concentrated serum made it difficult to employ. While some reactions (chills and fever), related by us to the administration of these materials, have been noted with normal pooled serum and pooled plasma, they have both been satisfactory within the limits of this type of therapy. Whole blood was used much, a number of years ago, and was also of undoubted value. As the red blood cells do not appear to be necessary or altogether desirable at this stage, plasma or serum are recommended. The amount of plasma necessary to control the hemoconcentration as evidenced by whatever estimation that is being used (hemoglobin, specific gravity, etc.) is large and bears some relation to the size of the burn. Ideally, to restore the original blood volume is the aim. From a practical point of view this should remain the aim if circumstances and supplies exist. Clinical improvement in patients with much smaller doses is remarkable, even without laboratory evidence of control of hemoconcentration.

Experience has taught that small burns (under 5 per cent) are not to be feared as far as mortality due to secondary shock is concerned. These, despite a degree of hemoconcentration, may be neglected as far as the attempt to maintain blood volume is concerned. Burns of over 10 per cent of the surface may be considered progressively more serious according to size. The necessity to provide agents to maintain blood volume also becomes increasingly urgent. As the flow of plasma into the tissues, and possibly from the surface, starts immediately, the intravenous plasma or serum should be started at once, without waiting for signs of distress on the part of the patient as evidenced by ordinary observation. Thus, the quantity of plasma is given empirically, additions being made as tests reveal the necessity. The majority of our patients having been children, we have worked on the basis of 3 c.c. of plasma per 1 per cent rise in hemoglobin per ten pounds of body weight.

If later the serum protein drop is significant or the hemoconcentration is not controlled, more plasma may be given. It is not our opinion that the apparently ideal quantity (i.e., the quantity necessary to completely restore the original blood volume as estimated by blood examinations, hemoglobin, hematocrit, etc.) must necessarily be given. Indeed, the use of such quantities might be criticized as wastful of material which is expensive, and which on administration is not entirely free from reactions of a disturbing character. Whether plasma serum or whole blood should be given, and in what doses, for intermediate or late therapy, need not be discussed in this communication.

It is only fair to state that while quantities given at the present time might on occasions seem unnecessarily large, the error occurs more often in the opposite direction. Many rules have been given by which the quantity may be estimated, such as by Harkins,[8] Black,[9] and Elkington, Wolff, and Lee.[10] This type of supportive treatment is commenced immediately in a burn of over 10 per cent in an adult. In smaller burns our policy has been to be guided by the clinical data as it developed. The intravenous apparatus in our cases has been kept running between the periods when the serum or plasma was being administered, with 5 per cent glucose or a mixture of glucose and normal saline solution. It is most important that fluid output (urine and vomitus) be carefully measured. In an adult a twenty-four hour urinary output of at least 1,000 c.c. is desired. For some hours after the accident, even in severe burns, the patient may take fluids well by mouth.

Concerning other supportive general therapy, the use of cortin has seemed in our experience to be of value. There is little beyond impression to support this, however. Its employment can safely be left with those conducting investigation. Its expense and scarcity are too great for routine use. Oxygen in high concentrations should be given to patients showing cyanosis. A slowed peripheral circulation and cyanosis is present in most cases of moderate or severe degree. There has been a tendency on our part to neglect this aspect of treatment.

Early Complications.—Mild jaundice is noticed occasionally. Beyond the usual supportive measures with glucose solution intravenously, no specific measures aimed at the cause of the lesion have been used by us. Vomitus containing changed blood is common. Massive hemorrhage may happen from erosion of the lower part of the esophagus or from stomach or duodenal ulcer; this is uncommon. Whole blood replacement is given. Uremia and anuria may occur and beyond the measures usually taken for these conditions nothing further has been employed. Chest complications due to associated respiratory tract damage must be dealt with as they arise. Oxygen is valuable. Two cases of mediastinal emphysema have been seen. In one no treatment was instituted and recovery took place. In the other case there was steady progression of the emphysema up over the neck and chest. A tracheotomy was per-

formed with temporary improvement. The patient later died, and the value of the tracheotomy was problematical. Pneumonia has been seen in a number of cases. Acute pulmonary edema has also been encountered. The giving of the large quantities of intravenous fluids (plasma and electrolytes) in such cases has been discontinued.

CONCLUSIONS

1. An attempt has been made to indicate one good method of early treatment so that the uninitiated faced with the likelihood of having to treat cases may be prepared both with the knowledge and the equipment to use one method well.

2. Emphasis has been placed on using the same materials and equipment for both first-aid and definitive treatment.

3. The topical application was discussed and the reasons given for the choice, with emphasis on simplicity.

4. The general measures associated with relief of pain and supportive measures were mentioned briefly. These have been discussed so much in recent literature that it appearaed useless to go into detail.

5. The early complications were mentioned briefly.

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REPAIR OF THE BURNED HAND

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CRIPPLING burns of the hand challenge the plastic and reconstructive surgeon. Together with his brain, man's hand, that beautifully engineered mechanism peculiar to genus homo, has been responsible for his commanding position in the universe. So delicately balanced and so interrelated in action are the components of its parts that damage to one part profoundly affects the functions of the other parts. The variety of movements of the wrist and of the thumb together with the fingers is astounding. This brief discussion aims to analyze some of the crippling injuries of the hand due to burns and to present our solutions for restoration of function.

The controversial discussion of treatments of fresh burns is purposely omitted and attention is focused on repair after the acute stage is past.

Because of its exposed position, the hand is frequently burned. A rapid review of the anatomic structure of the hand is a necessity for planning any reconstruction surgery, so that a proper evaluation of the tissue destruction may be had, and a proper selection of a plan of repair may be arrived at.

The dorsum of the hand and fingers is more frequently burned than is the palm. Here the skin is rather thin, soft, and pliable and there is very little subcutaneous fat in the superficial fascia. The deep fascia over the wrist is thickened to form the posterior annular ligament, which protects the tendons passing beneath, and which deep fascia then extends over the dorsum of the hand and fingers as a thin and delicate membrane. Here the deep fascia covers the extensor tendons but provides little protection for them where the burn is at all deep. Over the dorsum of the fingers there is little subcutaneous tissue and this, with the skin, forms only moderate protection to the tendons and joint capsules.

The volar surface of the wrist beneath the skin is protected by a thickened deep fascia, constituting the anterior annular ligament, below which pass the flexor tendons. The skin of the palm is heavier and characterized by a horny thickened epithelial layer. The superficial fascia of the palm is dense and thin and closely connects the skin of the palm with the deep fascia. The deep fascia in its central portion is dense and thick and protects the underlying vessels, nerves, and tendons from injury in all except the deepest burns. Over the thenar and hypothenar eminences the deep fascia is very thin. The skin of the volar surface of the fingers is much the same as that of the palm, but the fatty

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pads over each phalanx are thicker and with the denser tendon sheaths offer considerable protection against injury.

So it may be seen that in the palm the median and ulnar nerves with sensory branches to the fingers and motor branches to the intrinsic muscles of the hand, the superficial and deep flexor tendons and the arterial supply are well protected against quite deep burns.

The conjoined tendons of the lumbricales and interossei should be especially noted. Although these muscles are well protected in the palm their conjoined tendons pass along the lateral borders of the fingers and insert into the extensor tendons near the middle joints. Their function is important as they extend the middle and distal phalanges of the fingers, and their more exposed position permits frequent damage in many burns.

Burns of the hand vary in degree, of course. First degree burns may cause blisters and may result in sensitiveness and redness for months. Persistent furunculosis is often annoying. However, no surgical repair is needed.

Second degree burns, those through the skin and into the superficial fascia, cause dismaying deformities. The dorsum of the hand is more frequently burned than the palm, as probably the hand closes instinctively when it is threatened by fire.

As in burns of any part of the body, the incontrovertible dictum of grafting of denuded areas at the earliest moment possible is especially indicated for the hand. Granulation tissue is the parent of scar tissue, and the more granulation tissue that is allowed to proliferate the more scar tissue will result, with increased contractures, lessened blood supply, and greater dysfunction of the part.

The surgeon sees a great number of burns of the dorsum of the hand which are betwixt and between, in other words, burns which involve a part of the cutis vera, the specialized cells of the skin. After the acute stage of the burn and when the slough has cleared away, in a few days one sees a great multitude of tiny epithelial islands in the granulation tissue. These are the outgrowth of epithelial cells from the glandular structures such as hair follicles and the ducts of sudoriferous glands and sebaceous glands, which penetrate deeply and parts of which have survived the burn. The islands spread rapidly, coalesce and form a patina, delicate and bluish white, which thickens with increasing layers of epithelial cells. These burns will not require skin grafts. A period of toughening of the new epithelium and of restoration of function of the fingers must follow. The part must be guarded against blows, which easily cause hematomas under the new protecting cells, and scrapes, which with very little force slide off the fragile cells.

Although healing may be rapid and satisfactory with good return of function, this function may be lost and appearance marred by the so common keloid, which usually makes its appearance in from one to

three months after healing has occurred. This hyperplasia of fibroblastic tissue follows a high percentage of burns. One can hardly avoid considering it as a form of new growth as it differs from ordinary hyperplasia of scar tissue in that the fibroblasts follow out along the blood vessels and the growth spreads considerably further than the original tissue destruction. Wherever the true dermis is injured, keloid may occur, as well as in deeper burns. If allowed to progress unhindered the fibrous tissue piles up, often to astounding thickness, and later the aging cells contract, and with the hard thick scar, destroy or limit function. The ugly red gnarled surface is a deformity, and the intolerable itching and burning of the keloid area, especially in hot or cold weather, yields to no surface medication. If taken early, keloid can be inhibited or softened and flattened by roentgen ray therapy. We prefer the use of smaller divided doses at frequent intervals. Without treatment keloids usually pale out, soften, and flatten in from two to four years. Although faster than this, roentgen ray therapy is still slow, and the other alternative is reconstruction surgery, which is rapid. Complete excision of the offending scar with replacement by normal tissue serves both function and appearance. In other words, burn scars of this type and degree where extensor tendons and sheaths are intact can be quickly corrected.

Deeper third degree burns down through the fascia and tendons, even to the metacarpals, present a more difficult problem. Grafting with thinly cut skin should be done early to obtain an area free from infection before repair is attempted. This advice holds true in all but exceptional cases.

The palm of the hand presents the same problems as does the dorsum with some differences due to structure. The thicker palmar skin may give somewhat more protection, but the thinness of the superficial fascia quickly exposes the deep fascia, once the full thickness of the skin is burned through. While the deep fascia is indeed thick and a protection to the tendons in the middle of the palm, that part of the deep fascia over the thenar and hypothenar eminences is thin and easily destroyed, so that even the mild infection of the granulating stage may burrow down around the heavy central portion and attack the tendon sheaths beneath, freezing the flexor tendons within them. When keloid follows scarring of the palm contractions are more pronounced and disabling than on the dorsum, repair is more difficult, and contractures are prone to recur.

Third degree burns down through the deep fascia and flexor tendons present a seemingly hopeless picture. Reconstruction of functioning flexor tendons is a far more formidable task than that of restoring extensor tendons.

Burns of fingers and thumb present their special problems. On the dorsum second degree burns, especially those complicated with keloid,

checkrein flexion of the fingers. Burns at the tips may injure the nail beds and permanently deform the fingernails.

Deeper burns of the dorsal surface of the fingers involve the extensor tendons and also the tendons of the interossei and lumbricales, the importance of which was emphasized in the anatomic review. A deformity commonly seen with severe burns is complete loss of covering over the middle joints and complete loss of extension of the middle and distal phalanges. The contiguous articulating surfaces of the proximal and middle phalanges are often eroded and subluxation may occur because of the loss of ligamentous support. The ligaments of the interphalangeal joints consist of the anterior ligament and two strong lateral ligaments. Posteriorly, the extensor tendon covers the joint and takes the place of a posterior ligament, blending with the lateral ligaments. Because of this anatomic structure burns of the dorsum of the fingers need not be very deep to result in disruption of the joint. Contractures of the webs of the fingers are very common and are especially difficult when accompanied by much keloid. Such contractures are difficult to correct because of the lack of surrounding normal tissue to borrow from.

Over the thumb dorsum and over the first metacarpal, locking scars are common and demand complete removal for functional return.

The web between finger and thumb is very vulnerable to damage and contractures here commonly limit abduction to a marked degree.

On the volar surface of the fingers and thumb contractures are notable for great shortening and bowstring contractures, as they are called, are the rule. Extreme contractures in the palm, especially at the proximal third, are most disabling as they draw the thumb into the path of the flexing fingers and destroy the relations of the normal arch of the palm.

X-ray burns of the hand and fingers, often politely called roentgen ray dermatitis, demand special attention. The progress of degeneration in them is slow in most cases and only after years does the condition become alarming. We still see numbers of our fellow practitioners who pioneered in roentgenology and who carry the scars of these burns on the dorsum of the fingers. Others have been victims in the past of x-ray used as a depilatory by laymen, while still others have their mementos as a result of misjudgment of therapy dosage. There seems to be some lack of knowledge that the very different skin of the palm, just as that of the sole of the foot, has less resistance to the effect of the roentgen ray than has skin of other parts of the body. The picture is characteristic. Atrophy, scar, pigment disturbance, trophic changes, telangiectases, hyperkeratoses, and intractable painful ulcers make an easy diagnosis. The outstanding feature is the great frequency of malignant degeneration of the epithelioma type, especially in the areas of hyperkeratosis and ulceration. We consider temporizing and palliative treatment exceedingly dangerous. The very best insurance against cancerous degeneration in these areas is a complete removal of the offending tissue and replacement by normal tissue.

This rapid review of the anatomy of the hand with a survey of the pathologic distortions of that anatomy due to burns brings this discussion to the process of reversal of these distortions, as far as is possible, by reconstructive surgery. A perfect restoration is, of course, impossible but a return of function, contour, and appearance to a major degree is attainable.

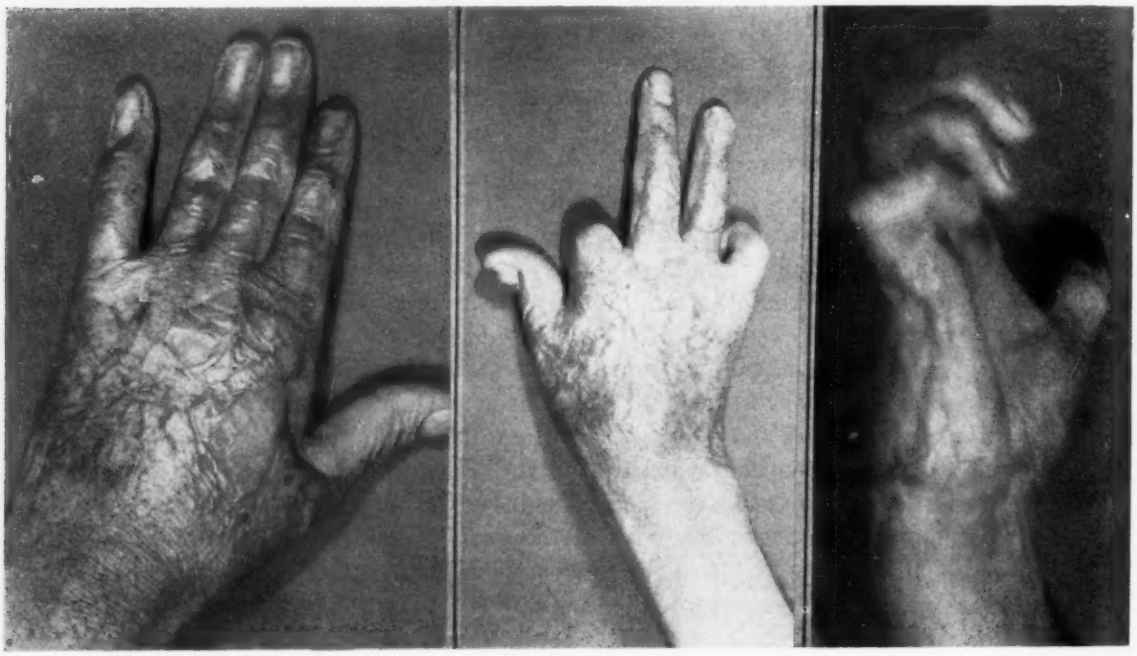
The error into which the surgeon most frequently falls in planning a repair of a devastated hand is an underestimation of tissue loss. When scars are allowed to resume their normal position, the amount of tissue needed to fill the defect is often surprising. Indeed, too often is a previously prepared flap dismayingly short of the mark and the results of the repair are disappointing.

To replace the destroyed tissue the surgeon possesses a variety of materials. Free skin grafts of various types, transposed flaps, and the tubed pedicle flap of Gillies are his major armamentarium. Davis grafts should be used almost never. Thiersch grafts are of little value for permanent repair because of a tendency to contract, but they are invaluable for quick healing of burns so that reconstruction may be started early. The split skin graft of Blair has a wider application, as it consists of epithelium and part of the corium, thereby providing a covering with many of the characteristics of full thickness skin. We are enthusiastic concerning the value of skin grafts cut with the Padgett dermatome. The even thickness of the graft gives a much better final result than any graft that we have been able to cut free hand. The machine enables the operator to choose the depth of skin required and the ability to take at least two-thirds of the corium. This insures a soft resultant graft with almost all the characteristics of normal skin, yet with a certainty of take that one could not hope for with a full thickness graft.

The following cases of deformity of the hand due to burns illustrate some of the common problems of this class and show the procedures used to repair the damage.

Fig. 1, *A* and *B*, shows both hands of a patient severely burned in a gasoline explosion, and Fig. 1*C* indicates the limits of flexion possible in one hand five months after the injury, when the patient came under our care. Since the scarred keloid areas could be moved over the deep fascia with the examining finger it was evident that skin grafts without subcutaneous fat could be used for repair. The left hand was repaired first. The scar was dissected off, under nitrous oxide and oxygen anesthesia, and a blood pressure cuff was used to obtain a bloodless field. When the pressure was removed bleeding points were tied with Lukens silk No. 00. The dissection cleared the entire area of the dorsum of the hand from just distal to the wrist to the middle joints of the fingers. A skin graft 0.016 inch thick, large enough to cover the defect in one piece, was taken from the abdomen with the Padgett dermatome. The

skin graft was sutured in place with 6-0 Dermalon suture and then splinted with gauze soaked in saline solution and marine sponges. Dressings were removed on the eighth postoperative day. A similar procedure was carried out on the right hand four weeks later. Fig. 1*D* shows the result three months fater the last operation, and Fig. 1*E* indicates voluntary flexion in both hands.

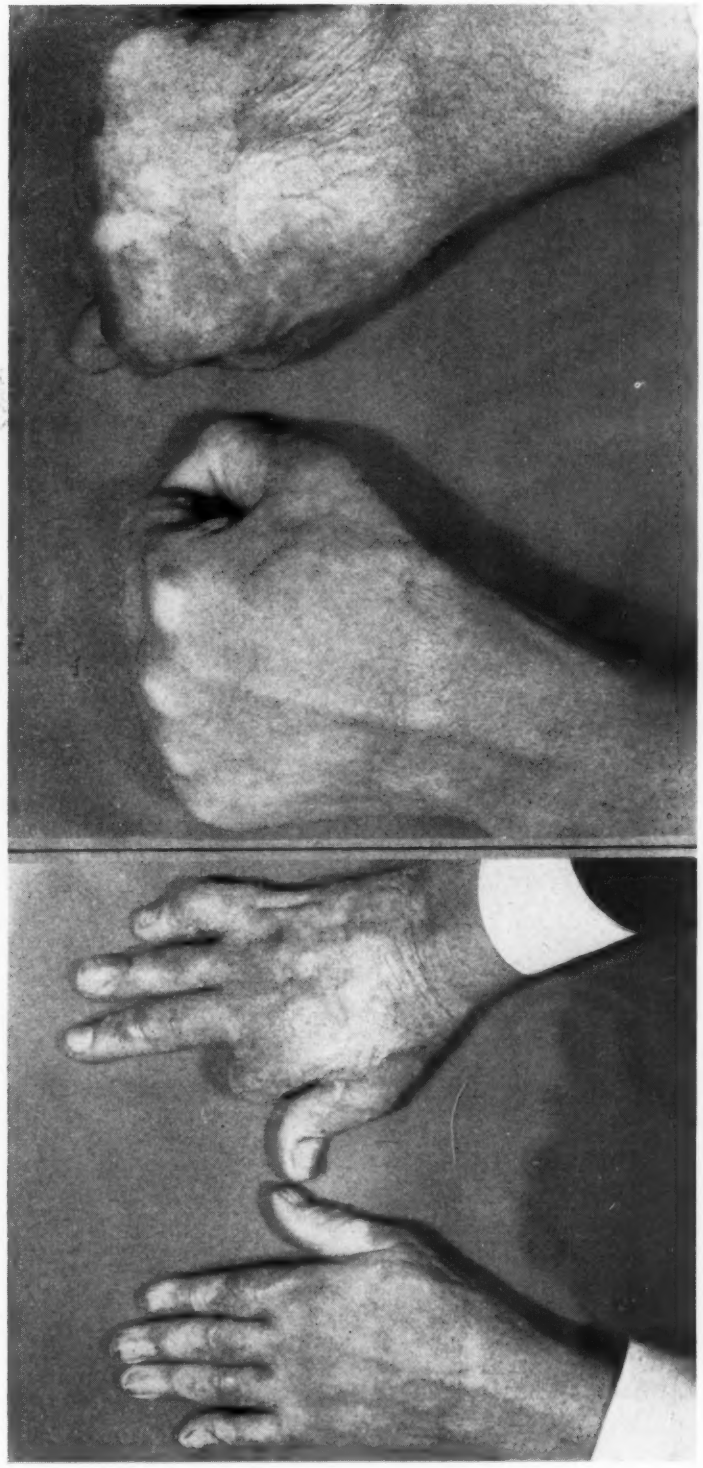


A. *B.* *C.*

Fig. 1.

Fig. 2, *A*, *B* and *C*, shows the hands of another patient, in Case 2, with similar burns and similar resulting keloid scars. Note especially in Fig. 2*B* the heavy keloid scar limiting abduction of the thumb. Fig. 2*D* shows the result of the grafting of skin by the same method as that used in Case 1. The grafts were also 0.016 inch thick. Fig. 2*E* shows the amount of abduction of thumb ten days after the scar of the web of the thumb was excised and a transposed flap of skin and subcutaneous fat was swung from the region of the radial side of the base of the index finger into the defect. This method of relieving such contractures is, in our opinion, superior to free skin grafts, as there is little tendency for the flap to contract.

Case 3 illustrates a rather bold procedure which has been previously reported by us.[1] Fig. 3*A* shows the heavy keloid scar of the dorsum of the hand and all the fingers which froze function. Fig. 3*B* shows a seven-pedicled flap on the abdomen to replace the entire area of scar. At the same time that the hand was placed under the flap the wound of the abdominal wall was grafted with split skin grafts and Fig. 3*C*



E.

D.

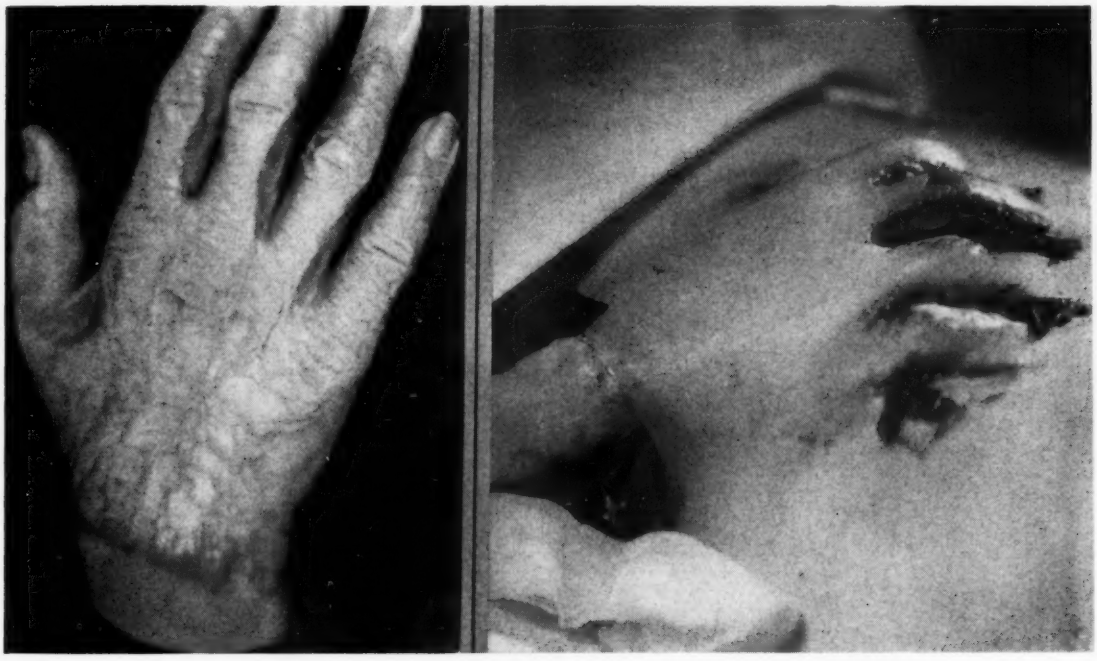
Fig. 1.

A. B. C.

D. E.

Fig. 2.

illustrates the healed area on the abdomen shortly after the pedicles were cut to free the hand. These pedicles were cut only one or two at a time, beginning two weeks after placement and finishing eight days later. The possibilities for extensive reconstruction of the hand are apparent, and the multipedicled flaps have the added advantage of many paths of return for the venous circulation. Venous stagnation is one of the surgeon's difficult problems in reconstruction employing flaps. Fig. 3, *D* and *E*, indicates the final result. Function was excellent and as the subcutaneous fat had been cut very thin there was no bulging of the graft.



A. *B.*

Fig. 3.

Case 4 illustrates a very heavy keloid scar which has locked the thumb (Fig. 4*A*). Fig. 4*B* shows the result soon after replacing the scar with a pedicled flap from the abdomen. Fig. 4*C* reveals the final result and the degree of flexion, rotation, and adduction possible in the thumb. This method is a better selection than is the use of a free graft for this particular problem.

The young lady in Case 5 had a number of moles on her hands. Too enthusiastic roentgen ray therapy resulted in this characteristic pathology which can be seen in Fig. 5, *A* and *B*. This devitalized skin is a potential source of malignancy. Thorough removal and replacement with normal skin and subcutaneous tissue by means of abdominal flaps insured against such future development.[1]

E.

D.

Fig. 3.

C.

C.

B.

A.

Fig. 4.

C.

B.

A.

Fig. 5.

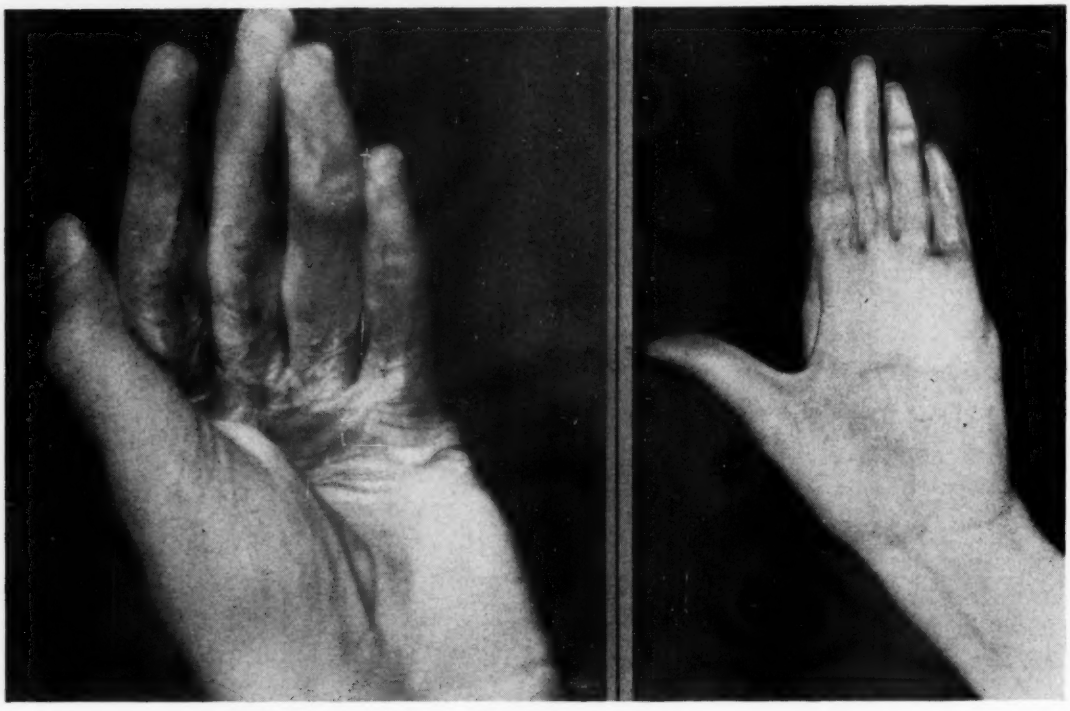
C.

B.

A.

Fig. 6.

The patient in Case 6 suffered very severe burns from a flareback of a furnace which he was tending. Among the worst of his burns was that of a hand, with destruction of the soft tissue of the dorsum down to the metacarpals. All tendons were destroyed. After healing had been obtained by Thiersch graft (Fig. 6*A*), reconstruction was accomplished with a double-pedicled abdominal flap to provide skin for covering and subcutaneous fat in which to graft extensor tendons (Fig. 6*B*). The double-pedicled flap assured an excellent arterial supply of blood and also a good venous outflow. The pedicles were severed after three weeks and the final result is shown in Fig. 6*C*. Unfortunately, this was final, as the patient died of a brain tumor three and one-half months later, before tendons could be grafted.[1]



A. *B.*

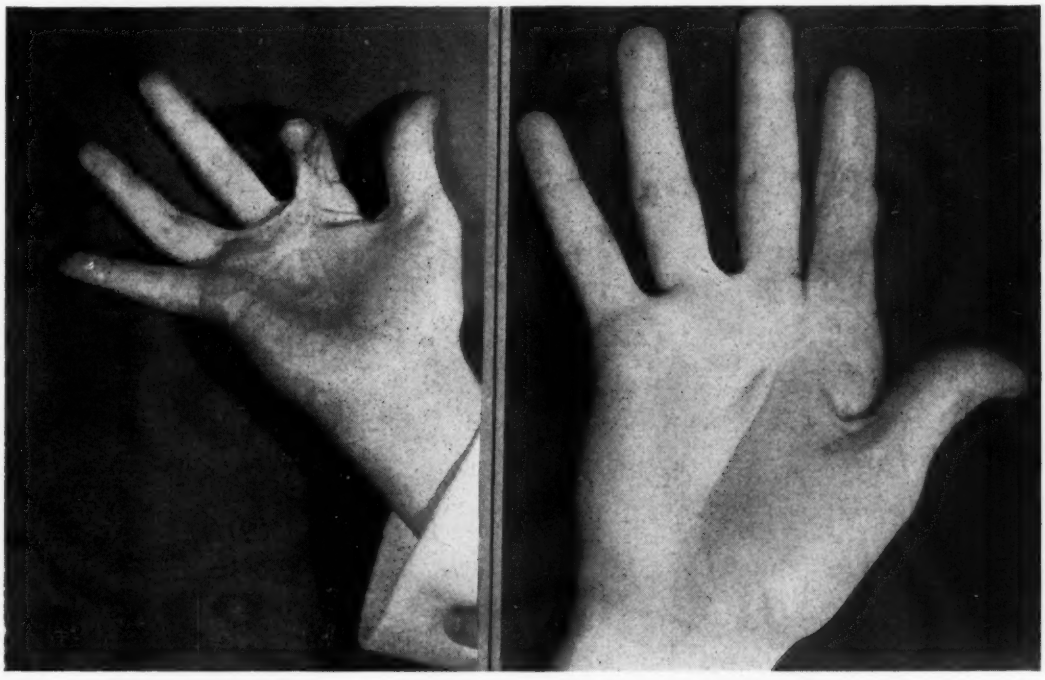
Fig. 7.

Case 7 is that of a severe burn of the hand and fingers with contracture of keloid scar between the distal half of the palm and the bases of the fingers. A similar method of repair as that used in Case 6 was employed, as the burn was deep, even through the palmar fascia. A worth-while functioning hand was obtained.

A burn scar of the volar surface of the finger is disabling and most inconvenient when contracted as that in Case 8 (Fig. 8*A*). The scar was dissected out and the resulting raw surface was grafted with a split skin graft of the Blair type, which was splinted with dental modeling

wax. Excellent extension was obtained. At present we would select by preference a graft cut with the Padgett dermatome about 0.022 inch thick.

While employed in a laundry, the patient in Case 9 caught her hand in a hot mangle. Eleven minutes passed before the hand could be released so that the fingers and distal half of the palm were quite thoroughly cooked. When first seen by us the hand was healed with the fingers a fused mass of scar (Fig. 9*A*). Restoring any function to the fingers or even saving them appeared to be a rather hopeless task, but it was undertaken at the insistance of the patient, but little was promised. At the first stage of operation the fingers were dissected out and found



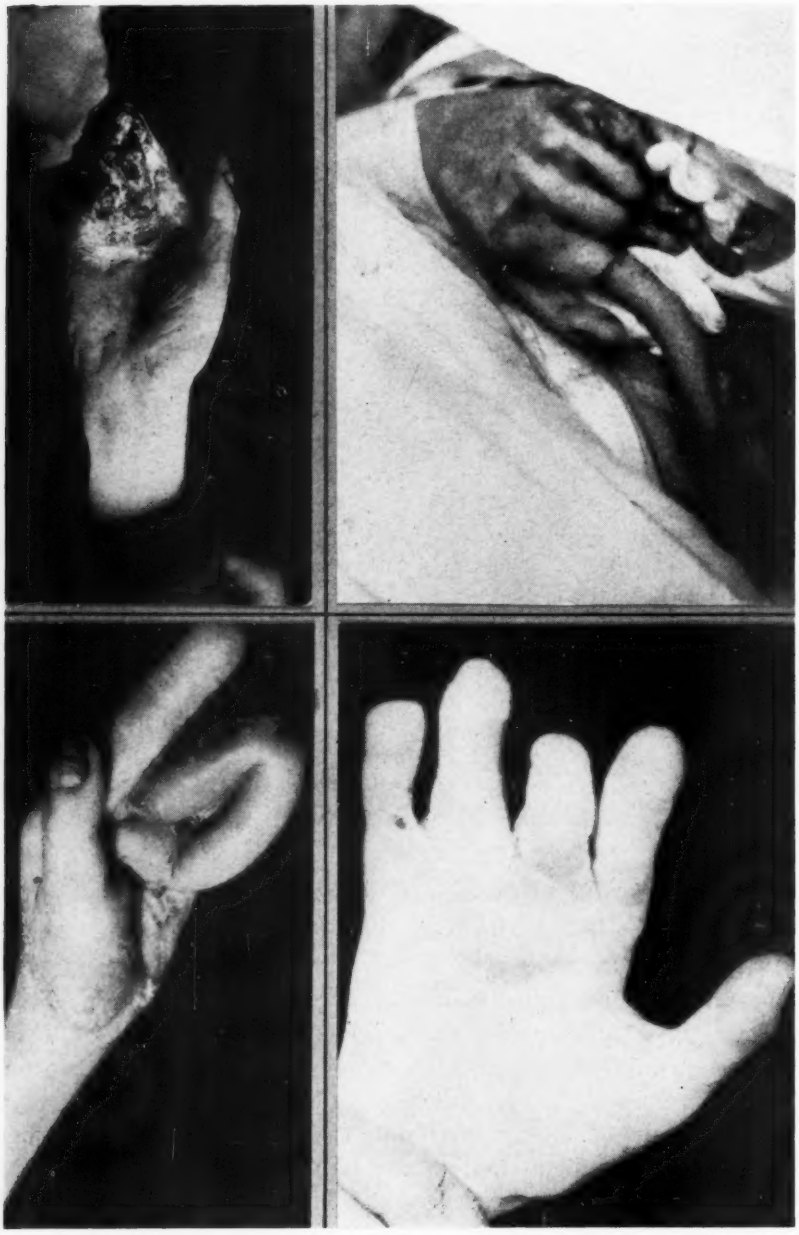
A. *B.*

Fig. 8.

to consist of little more than bone and ligaments, fortunately with good skin on the dorsum of each up to the middle joints. The next step was the preparation of a tubed pedicle on the abdomen. After healing, one end was cut off and applied to the index finger (Fig. 9*B*). This was cut off at appropriate length after three weeks. Another tubed pedicle was then prepared on the abdomen and, when healing was complete, one end was lifted and sutured into the defect left after removal of the scar from the distal half of the palm. After three weeks the abdominal end of the pedicle was cut free and swung onto the middle finger (Fig. 9*C*). Six weeks later the pedicle was cut free at its palmar base and the remainder transferred to the ring finger, the circulation

coming from the continuation of the pedicle on the middle finger. After three weeks the pedicle was severed and the tips fashioned. The final stage employed a small abdominal tubed pedicle applied to the little finger. The result is shown in Fig. 9*D*, and the procedure was most worth while, as the fingers could be flexed almost to the base of the

A. *B.*



C. *D.*

Fig. 9.

palm and, with the excellently functioning thumb, constituted a useful hand.[1]

After reconstruction has been completed, our task is still unfinished as the patient requires our aid in restoring function. Joint motion is limited in most cases. After many years of experience with the heat and massage treatments of physiotherapy we have discarded them entirely for injured hands. The finger joints react badly to any forced manipulation and we have adopted simple elastic traction to take its place. The patient takes the rubber bands home with him and applies them himself. We recommend off and on periods varying with the problem presented. The patient will never damage the joints with excessive manipulation. After each removal of the bands we instruct the patient to massage the joints, never rubbing the finger over the skin, but deep massage moving the skin with the massaging finger. The middle and distal joints can be rolled between the thumb and finger. Exercise should be encouraged. The results are often surprising. The application of the rubber bands is illustrated in Fig. 10*A* for the distal joints, Fig. 10, *B* and *C*, for the middle joints, and Fig. 10, *D* and *E*, for the metacarpophalangeal joints. Multiple rubber bands can be used in combinations.

A condition occasionally arises following burns which is also frequently seen associated with crushing or lacerating injuries of the hands. An area of irritation along the course of a nerve or blood vessel sets up a series of impulses resulting in an abnormal vascular response.

The patient presents a characteristic picture. The hand is cyanotic, clammy, and moist. It is held in a position of semiflexion and the patient resents any attempt at manipulation. There is atrophy of the soft tissues with swelling about the joints of the fingers. The skin is smooth, shiny, and delicate and has lost most of the natural skin folds and markings, which is most noticeable on the dorsum. The patient complains of pain of a vague aching or burning nature, which is almost continuous day and night and is aggravated by cold weather. The pain often radiates to the wrist, elbow, or shoulder. There may be paresthesia, anesthesia, or hyperesthesia of the fingers or hand. The grip is weak and the hand is almost useless. These patients are often classified as hysterical, neurotic, or malingerers, although most of them are very sincere in wishing to be rid of their symptoms. A closer analysis shows hypoesthesia to pinprick which may be almost complete, involving one or two fingers, or the entire hand in a glove distribution. It is the bizarre pattern of nerve findings which masks the true organic nature of the syndrome, and which accounts for the repeated diagnosis of compensation neurosis. Along with atrophy of the skin and soft tissue, there is shortening of the capsular ligaments of the joints so that the

fingers and wrist become stiff, and attempts at motion are painful. This in turn leads to further atrophy of disuse.

The mechanism of the lesion is not yet known, although it has been closely studied by Leriche and others. There are two factors working

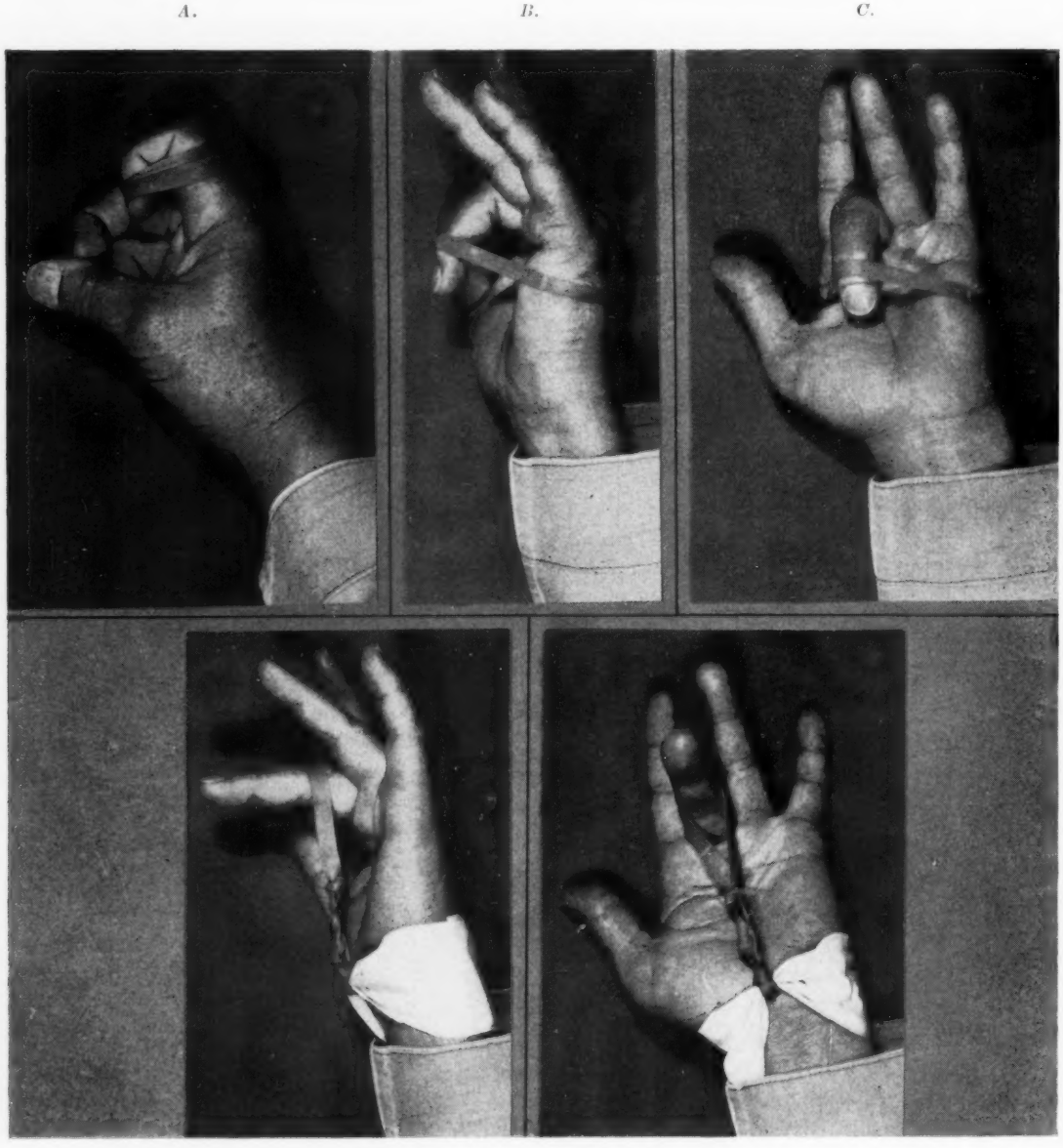


Fig. 10.

in contradiction to each other. The original pain, arising from a damaged nerve or blood vessel, evokes a vasoconstrictor response, along with other evidence of sympathetic hyperactivity such as local sweating. The vasoconstriction increases the pain and adds the quality of aching

and diffuse radiation. Any factor which tends to increase the vasoconstriction, such as cold weather, likewise increases the aching, cyanosis, hypoesthesia, and stiffness in the hand.

Opposed to this is a reflex, compensatory increased blood flow to the entire upper extremity, which gives the pain the quality of paresthesia, burning, and tingling. In hot weather, when the vasodilatation factor is at its height, these latter symptoms are the most annoying. The studies of Miller and deTakats show increased blood flow as a constant finding, and furthermore show that after cervical sympathectomy the blood flow is increased even more. As the vasoconstrictor effect of the sympathetics is now abolished, the pain disappears and the hand approaches normal.

TREATMENT

1. Early diagnosis is of prime importance, as the soft tissue atrophy may lead to irreparable damage, especially in regard to stiffening of the joints.

2. Interrupting the vicious cycle of vasoconstriction is brought about by injections of 1 per cent novocain around the ulnar and radial nerves and arteries at the wrist. This is the most effective step of the treatment, and should be done twice a week at first, then at longer intervals, as indicated. The immediate effect of the injection of novocain is remarkable. The hand which was pale and cyanotic becomes flushed and warm, the sweating stops, the pain is eased, and the grip may be increased from 20 kg. to as much as 50 kg. within ten minutes. The joints are more flexible and are not so tender. There may be complete anesthesia for an hour or two, after which sensation returns, but areas which were anesthetic or paresthetic before are more nearly normal. After a few hours or days the symptoms and signs often reappear. For this reason it is necessary to keep the patient under observation and repeat the injections as often as necessary. Occasionally a single injection is sufficient to effect a cure.

3. During treatment the hand should be allowed to rest in a position of comfort, held in a sling to support the circulation as far as possible. It is best to avoid any form of passive manipulation or physiotherapy in the early stages.

4. Time is the great healer, and with the aid of novocain injections, gentle elastic traction, and carefully supervised return to active use, many of these patients are rehabilitated. Their mental attitude plays an important role and special care should be taken to get their complete cooperation, and to encourage them as to the eventual return to useful work. In very persistent cases, Leriche and others advocate injection of the cervical stellate sympathetic ganglion, or even its surgical removal. In their hands this is an effective, though radical, method of treatment if done early enough.

CONCLUSION

Restoration of function and appearance of the burned hand demands a thorough knowledge of the anatomy and physiology of the part. The amount of tissue loss and tissue damage must be accurately gauged, and the repair must be planned accordingly. Skin grafts and skin flaps provide the material for reconstruction and the type to be employed must be judiciously selected. Proper means must be employed to obtain the utmost return of function. We still fall far short of our desired goal, and much progress by the surgeon remains to be made in reconstruction surgery of the burned hand.

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PLASTIC REPAIR OF EXTENSOR HAND CONTRACTURES FOLLOWING HEALED DEEP SECOND DEGREE BURNS*

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THE present conflict with its newer types of warfare equipment has given rise to many burns among the military personnel. Blasts from high explosives and the fires from burning oil have produced a type of injury that has not been observed to the same degree either in previous wars or in civilian practice. While any exposed surface is subject to injury, one of the more frequent sites is on the extensor aspects of the hands. So commonly are these seen, that they might well be looked upon as an occupational injury. When a bomb explodes, a "flash burn" is likely to occur to those working near by. The personnel within range will unconsciously place their hands in front of their faces and consequently the brunt of the flash burn takes place on the exposed extensor surfaces of the hands and fingers. Since the forearm is usually covered by a shirt or blouse, these areas are ordinarily spared. In naval warfare, an enemy plane not uncommonly crashes on the deck of a ship. When an explosion follows, flaming oil and gasoline are sprayed about in all directions. Those unfortunate enough to be working within range are often burned by the spraying flames. Again the dorsal surface of the hands and fingers is exposed to the flaming material dropping from above. As one would expect, the majority of these injuries are bilateral.

SYMPTOMS

While burns arising from these sources may be classified into the first, second, and third degree types, the scope of this communication deals chiefly with those second degree in character. As a matter of interest, however, it is fortunate that the percentage of third degree burns is in the minority. Healed superficial second degree burns produce no problem worthy of mention here, but those of the intermediate group apparently have not been too well understood.

The deep second degree burn will naturally heal spontaneously because of regeneration from the remaining deeper elements of the skin and sebaceous glands. Unfortunately, however, a large amount of fibrosis develops in this newly formed covering and at times it is of sufficient degree to make difficult the distinction between it and those contractures arising from third degree burns that have been permitted to

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*The opinions and views set forth in this article are those of the writer and are not to be considered as reflecting the policies of the Navy Department.

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heal spontaneously by epithelization. The covering is rough, dry, and scaly and in many instances develops a keloidal type of hypertrophy. Complete flexion of the fingers is difficult or impossible because of the inelasticity of the covering. Forced attempts to produce flexion cause the skin to crack and break open over the metacarpophalangeal joints. The circulation is impaired so that in cold weather the damaged areas become cyanotic and tend to break down if not protected.

The symptoms pointed out are very apparent to all those who have dealt with injuries of this type. The situation is, of course, most pronounced in a kinetic structure such as the hand but might well be of little importance in a surface of lesser mechanical activity, as, for instance, the back or abdomen.

A. *B.*

Fig. 1.—*A*, Healed deep second degree burns of right hand with marked limitation of flexion of fingers and wrist joint. *B*, After excision of dorsal contracture and replacement with thick split-thickness skin graft. Note flexion permitted by this near-normal elastic covering.

PATHOLOGY

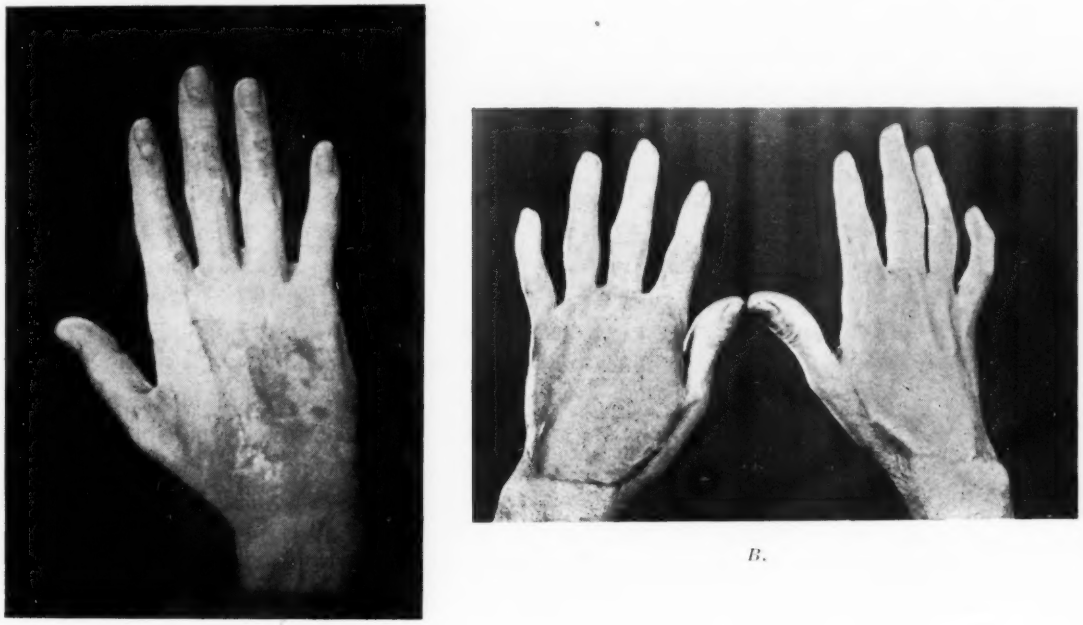
A study of a typical microscopic section of this tissue shows the surface to be covered by keratinized stratified squamous epithelial cells whose rete pegs are flattened and in some areas absent. The connective tissue is poorly vascularized and is almost acellular. The subjacent tissue is dense and fibrous.

TREATMENT

The correction of the contractures that follow deep second degree burns always has been handled from the more conservative point of

view which unfortunately has often fallen short of yielding the most desirable end result.

Physiotherapy in all forms has been utilized to treat injuries of this type. Occupational therapy, too, has been added. Irradiation in an attempt to soften and prevent fibrosis is likewise a favorite treatment. However, many of those with deep damage show very little response because of the unyielding fibrosis that extends throughout the healed epithelial covering. Consequently, the symptoms continue to persist until the fibrotic covering has been completely excised and replaced with another having normal elastic characteristics. In view of these findings it has been our experience that the conservative attitude in the management of this type of burn complication has given very unsatisfactory results.

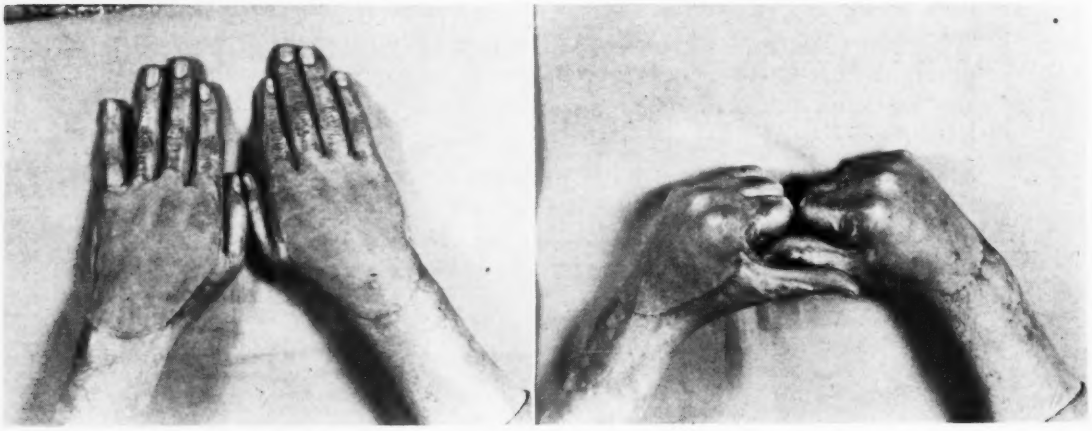


A. *B.*

Fig. 2.—*A*, Thick fibrotic dorsal covering on right hand. Left hand was in similar condition. *B*, Condition of both hands after excision of damaged extensor surfaces and replacement with thick split-thickness skin grafts.

Assuming the other viewpoint of what at first seemed more radical has in the final analysis compensated both the surgeon and patient with a far superior permanent covering. Being dissatisfied with the poorer end results, we have been following the policy of excising these fibrotic coverings as soon as it becomes apparent that further spontaneous improvement is hopeless. After excision, the cutaneous defect is covered immediately with a properly selected type of skin graft. The type chosen must furnish good elasticity in its substance and at the same time avoid utilizing complicated technical methods.

Our operations are done, preferably, under local anesthesia. This aids in hemostasis and, since the operation is not of brief duration, the additional burden of general anesthesia is avoided. Premedication consisting of nembutal, 4½ gr., two hours before surgery eliminates subjective apprehension. As a matter of fact, most patients sleep through most of the operation but can be aroused at any time to answer questions.



A. *B.*

Fig. 3.—*A*, Result after replacement of extensor contractures with thick split-thickness skin grafts from chest. *B*, Note excellent elastic coverings provided by this relatively simple type of skin grafting procedure.

A blood pressure cuff placed around the upper arm and maintained at a pressure of 200 mm. of mercury gives, in conjunction with the local anesthesia, a very dry operative field. In the process of excising the scar, one must be careful not to injure any of the underlying dorsal veins or subcutaneous fat. At the completion of this step the blood pressure cuff is released and hemostasis perfected with ligatures and hot compresses to perfect the bed for the reception of a skin graft. More recently, we have found it expedient to coagulate all minor bleeding points with diathermy. This maneuver has not seemed to interfere with the "taking" of the graft and at the same time reduces materially the operative time.

Since the underlying tendons are in the most part covered with a good subcutaneous fat pad, any type of pedicle flap is unnecessary. Occasionally a small segment of tendon may be exposed in part, but this can be closed by suturing over it a small portion of the adjacent fat. The defect may be covered with either a free full-thickness or a thick split-thickness skin graft, cut in one massive piece. All of our cases have been closed by the latter method because of its relative simplicity. These grafts are cut in one large segment to approximately 85 to 90 per cent total skin thickness. This serves to give a strong flexible covering and at the same time leaves enough of the deeper elements of the skin so that the donor site heals spontaneously.

The grafts may be cut either with the Padgett dermatome or the Blair-Brown suction box and razor technique, depending upon the skill of the individual operator. We have used the thigh, abdomen, and chest for donor sites with uniform success. It must be pointed out, however, that grafts from the chest and abdomen can be taken with greater accuracy when the Padgett dermatome is used.

After cutting, the graft is secured to the defect on the hand and fingers with nonabsorbable sutures. Slits are cut in the distal end of the graft to fit over the fingers. Pressure dressings are applied and the hand and arm immobilized on a padded straight board splint. For pressure we prefer ordinary flat sterile gauze dressings and abdominal pads, feeling that we obtain a more even and flat distribution of pressure than is secured with some of the other dressings in current use.

Barring complications, the dressing is not touched for seven to eight days, following which it is removed. At this time the sutures are removed and any excess graft trimmed off. The pressure dressings are reapplied for another week. Beginning two weeks after the operation, the coverings are removed for daily soakings and passive exercises in warm sterile water. At the end of three weeks, healing has usually progressed to the point where all pressure bandages can be removed permanently. More active physiotherapy and use are then started and at the same time the patient is encouraged to resume gradually all normal activities. An early return to limited duty is permitted providing trauma is avoided until good sensation has developed in the grafted skin. This latter factor will ordinarily take from six to twelve months but should not be of any handicap if simple precautions are observed.

CONCLUSIONS

1. Deep second degree burns of the dorsal aspects of the hands and fingers are quite frequent in modern warfare.

2. While burns of this type heal spontaneously, a thick fibrotic covering commonly develops thereafter, which does not respond well to conservative therapy.

3. Replacement of the damaged skin by a single massive thick split-thickness skin graft gives an excellent final result.

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REHABILITATION FOLLOWING SEVERE BURNS

Experiences With Victims of the Boston Night Club Fire

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INTEREST in the management of severe burns has been greatly stimulated by World War II and the recent night club fire in Boston. In the early general care of the burned patient, the importance of adequate plasma, of oxygen, if there has been damage to the lungs, and of general supportive measures is generally agreed upon. In the later care, transfusions and diets with adequate vitamins, minerals, proteins, and calories are vitally important and also generally agreed upon. Concerning the local care of the severely burned, however, there is not the same unanimity of opinion. The purpose of this communication is to discuss the early and late local care on the basis of the experience with the victims of the Boston fire treated at the Massachusetts General Hospital.

Ten of the thirty-nine patients admitted on the night of the disaster remained in the hospital more than two weeks because they had third degree burns of sufficient extent to require further treatment. Two guiding principles were followed in the management of these cases: one, to preserve and protect the unburned tissues from additional damage, and the other, to close the open wounds as early as possible with skin grafts. In this small group of patients with deep burns it was possible to evaluate the unorthodox method chosen for treatment, since every effort was made to control the factors that are known to cause cell damage and that are known to delay the optimal time for grafting. Many surgeons have held the opinion which Graham has wisely stated, "In comparing the values of different . . . treatments of burns, it is, of course, essential to bear in mind that the only kind of case which offers a real test is the third degree burn. Almost any form of treatment, if it is not harmful" and, he might have added, if it is not complicated by serious infection, "will suffice for the first and second degree varieties. Too often this simple fact is overlooked."

Invasive infection is the most serious and the commonest cause of destruction of living epithelial cells in the deeper layers of the skin and tissue cells in the subcutaneous layers. The bacteria causing this infection are seldom present immediately after the burn occurs, because many of the surface organisms, as well as the skin, are destroyed by the heat. They reach the wound by injudicious exposure of the burned surfaces to unclean surroundings with unmasked observers. The rehabilitation of the severely burned must start at the time of the first inspection of the

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wound by reducing contamination to a minimum. Therefore, all persons caring for the victims of the disaster, doctors, nurses, orderlies, and medical students, were masked and wore clean gowns.

On admission the patient's clothing, which, in most cases, was soaked by water from the firemen's hoses, was removed and the patient placed on a sterile sheet. The burned surfaces were carefully wrapped in sterile towels until measures to correct shock and improve the general condition had been instituted. The victims were transferred to a special casualty ward—a regular ward from which all patients had been evacuated. This became an isolation ward (masks, clean gowns, and restricted admission), and here, while the necessary plasma was being given, the definitive treatment of the burned surfaces was carried out with as careful asepsis as possible. Subsequent dressings were done in an operating room established in this ward and, later, when the special ward was discontinued, in a regular operating room reserved for these patients exclusively.

Common surgical practice in the definitive treatment of the burned surfaces has dictated careful débridement. All destroyed epithelial tissue is removed, and all blebs ruptured and the walls trimmed away to allow the escape of coagulated and uncoagulated serum beneath. The surface is then cleansed either by irrigation with sterile saline solution or by scrubbing with soap and water. Finally, tannic acid (Davidson) or one of the dyes is sprayed on the surface. Recently, from the teachings of Brown and McDowell and Allen and Koch, a fine mesh ointment gauze with an occlusive dressing is applied. The procedure is usually done in an operating room with full personnel on hand to assist. It must, however, be postponed until the patient is completely recovered from shock, because general anesthesia may be necessary and because the débridement itself is accompanied by considerable loss of tissue fluid which may cause a secondary fall of blood pressure. The delay in completing the definitive treatment opens the way to surface contamination because of the inadequate protection afforded by the hastily applied sterile towel or sheet.

In the victims of the Boston night club fire treated at the Massachusetts General Hospital, accepted surgical practice was not followed. No cleansing or débridement of the burned skin was done. All blebs were left unruptured. The definitive occlusive dressing was applied directly to the undisturbed surface. The procedure was carried out in the special casualty ward without anesthesia. In fact, some of the patients were still in moderate shock at the time. All wounds, however, were adequately covered within two and one-half hours after the first victim arrived.

This unorthodox method of treatment was not chosen because of inadequate help or inadequate facilities. Actually the hospital was well prepared for just such disaster because of plans made during the previous

eleven months to care for casualties from possible enemy action. There were well-organized surgical teams within call, there were abundant sterile surgical supplies on hand, and there was an efficient blood bank with large quantities of available plasma. The choice of method of treatment was deliberate. It was the result of a series of studies by members of the staff on problems related to burns, particularly the control of infection by chemotherapy and the effect of various agents on epithelial regeneration.

No débridement of the burned surfaces was done because evidence accumulated indicated that an increase in contamination of the wound resulted. Only by vigorous scrubbing of the surface could this contamination be reduced. However, the trauma of such scrubbing necessarily causes damage to viable cells and reduces the effectiveness of the important factor of tissue resistance in preventing invasive infection. All blebs were intentionally left unruptured and no surface debris was disturbed. This plan was justified by the absence of growth in cultures of bleb fluid taken at intervals after the burn in these and other patients. Such results indicate that the intact outer wall of the bleb acts as adequate protection, preventing the penetration of pathogenic organisms from without. Even the epithelium lying on the surface after rupture of a bleb acts as a protecting membrane and was not removed. Each patient was given a prophylactic dose of 2 Gm. of sodium sulfadiazine intravenously about three hours after admission. Subsequently, sulfadiazine was given by mouth in dosages of 6 Gm. daily. No sulfonamides were used locally for two reasons: first, because of inability to control absorption accurately and, second, because evidence from clinical studies indicated that the sulfonamides are present in effective concentrations in the bleb fluid even if the initial dose is given as late as forty-eight hours after the burn. Sulfadiazine determinatives in these and other patients with early administration of the drug revealed practically identical concentrations in the blood and bleb fluid. On the sixth day in one patient, a level of 6.7 mg. per cent of sulfadiazine was found in the bleb fluid, with an associated level of 6.6 mg. per cent in the blood. After confirming the above observations, a case was selected for delayed administration of the drug. A single dose, 4 Gm., was given two days after the burn. Twelve hours later bleb fluid and blood samples were taken. A level of 3.0 mg. per cent of sulfadiazine was found in the bleb fluid, with a level of 6.0 mg. per cent in the blood.

The reliance on tissue resistance and internal chemotherapy to control invasive infection was justified by the finding of hemolytic streptococcus in only two cultures among all the surviving patients. Both of these were taken at the first change of dressing on the fifth or sixth day. Cultures from areas of second and third degree burns at this time showed coagulase positive staphylococcus and gram-negative saprophytes. Subsequent cultures from these areas showed an increasing number of

saprophytes and decreasing numbers of staphylococci, except in the areas of third degree burn in which the staphylococci flourished in the slough. Although surface infection was present in the slough, there was no evidence of invasive infection in the surrounding skin. Marginal areas of second degree burn were well healed by the time the slough began to separate, and there was no evidence that any areas of second degree burn were converted into areas of third degree because of infection.

The average time before complete separation of the slough was twenty-five days. This is a longer interval than one normally expects the process to take. The relative freedom of the wounds from invasive infection may be of significance, since little pus and no abscesses were found beneath the slough when it was finally removed. In one patient, extensor tendons of the index and middle fingers were found exposed over the metacarpophalangeal joints for a distance of from 3 to 4 cm. The surrounding granulating wound, from which coagulase positive *Staphylococcus aureus* and *Bacillus proteus* were cultured, involved most of the back of the hand and extended to the tip of the proximal phalanges. In spite of the presence of staphylococci in the wound, these tendons were salvaged by being covered with a direct abdominal flap on the twenty-eighth day after the burn. Such a procedure would be hazardous in a wound with active infection.

The application of injurious agents on the freshly burned surface is another common cause of death of cells undamaged by the heat. Experimental studies on the rate of epithelial regeneration have been recently carried out comparing various agents recommended in the treatment of burns. The donor site from which a dermatome graft had been cut was used for this study because an epithelial defect of uniform depth was produced and because the factor of infection in retarding healing was eliminated. Comparisons of the rate of epithelial regeneration were made in subdivisions of the same donor site. Boric acid ointment, 10 per cent, lightly impregnated in a single layer of fine mesh gauze and held in place with a firm dressing was used as control treatment. The rate of healing beneath this dressing was compared with that of tannic acid, the dyes, and several ointments recommended in the treatment of burns. Healing with the control boric acid ointment gauze and the other ointments took place in about ten or twelve days but was delayed beneath the escharotics, in one patient as long as sixty days.

Since the above evidence indicated that the tanning agents delay healing, none were used in these victims. In the definitive dressing, fine mesh gauze lightly impregnated with boric acid ointment similar to that used in control treatment in the experimental studies was applied. The ointment gauze was placed carefully and evenly on the burned surfaces and covered with gauze sponges. In order to secure a resilient occlusive dressing, mechanics waste and an encircling bandage were applied. In the extremities the occlusive nature of the dressing seemed

to reduce the amount of plasma that escaped into the tissue, but about the face there was a redistribution of the escaping fluid with edema descending down the unburned chest wall below the level of the dressing.

The second guiding principle in the management of these patients was the closure of the open wounds as early as possible with skin grafts. The temptation to wait until burn wounds heal spontaneously is great, but many are so large that healing will never occur. Also, the epithelium in spontaneous healing is of poor quality and is easily damaged by the slightest trauma. But successful early closure by skin grafting demands aggressive and painstaking attention to local dressings and general supportive measures.

The reasons for early grafting seem obvious. First, a large unhealed burn is a debilitating lesion. There is chronic sepsis in the wound with loss of protein and body fluids. Progressive anemia is usually present. The patients become more emaciated as they draw on their body reserves. Only with concentrated feeding by mouth and supplementary intravenous feedings and transfusions can they be carried through the preliminary stages before grafting is done. For these reasons, each of the victims, after recovering from the initial shock, was given a carefully planned high protein, high caloric, and high vitamin diet. This was supplemented by intravenous feedings of amino-acids and by transfusions if clinical and laboratory observations indicated the need. The most severely burned patient received a total of twenty-five transfusions and daily amino-acids intravenously for about two weeks before the first graft was done.

The development of contractures can be avoided only by early covering of the raw surfaces with skin grafts. The normal healing of an open wound involves two processes: reduction in the size of the defect by contraction of scar tissue and epithelialization of the raw surface from the margins. The larger the wound, the greater will be the contraction before healing takes place, but in some instances contraction continues and complete epithelialization never occurs. Among the victims the first graft was done on the twenty-third day after the disaster and the last at four months. Most of the operations were done during the sixth week. A minor contracture developed in the neck of the most severely burned patient. There were no others, but on the back of the hands of two patients thick keloid has developed which will require further corrective procedures.

Maintenance of the patient's morale is another reason for early grafting. No group of patients suffers more mental and physical torture than the severely burned. The pain of repeated dressings tests the courage of the most stoical and may necessitate anesthesia for dressings. Morale is hard to maintain unless great care and patience are used in changing dressings and unless promise of relief can be given by early covering of the painful surfaces with grafts. There is always a striking change

in attitude when the wounds are closed, and one of the most striking is the return of normal appetite, resulting in a prompt gain of weight.

The final reason for early grafting is economic. The hospital stay can be reduced by grafting the burned surfaces early. Otherwise, it may be prolonged many months or even years. The average hospital stay of the victims of the disaster was eleven weeks, the minimum was three and one-half weeks, and the maximum, twenty weeks. During this time, one or more skin grafting operations were done on nine of the ten severely burned patients. The tenth patient had a small area of deep burn on the back which rapidly healed from the margins without grafting.

In preparation of the raw surfaces for grafting, constant wet dressings were applied with moderate pressure. The progress in clinical improvement of the wounds was checked by repeated cultures. At each change of dressing the surfaces were carefully cleaned with soap and water and loose debris mechanically removed. It would have been better to alternate the wet dressings with ointment dressings, but the patients did not tolerate the change because of the discomfort of the drying in the latter type of dressing. The constant moisture seemed to delay the reduction of edema in the granulations and the development of a firm smooth surface free from organisms, such as *Bacillus pyocyaneus* and hemolytic streptococci, which are known to interfere with successful grafting. Sulfanilamide powder in controlled doses was dusted on the granulations preoperatively in several instances. The edema subsided, and the surface drainage decreased with the treatment more rapidly than with the wet dressings alone. In two patients there was loss of graft on the backs of the hand. One of these patients had a plasma protein level of 5.5 mg. per cent at the time of operation, and in the other beta hemolytic streptococci were found in the wound. There were no losses of graft following the local use of sulfanilamide.

The split thickness graft is the ideal graft for covering large and small surface defects from burns. Large sheets of skin are available, and the donor site is healed in about two weeks with little or no scarring. Several crops can be taken from the same area if the donor sites are limited. In these cases split thickness grafts were used to cover the raw surfaces with the single exception of the patient mentioned above who had extensor tendons exposed and in whom a direct abdominal flap was used. A flap applied to a granulating surface is indicated only to preserve or protect moving structures which might be destroyed or whose function might be impaired if not covered promptly with skin and subcutaneous tissue bearing its own blood supply. The use of pinch grafts in burn defects is not advisable for several reasons. The surface grafted has an ugly mottled appearance occasionally with keloid between the grafts, and the donor site is badly scarred. Exposed surfaces covered with these grafts do not withstand mild trauma. None were used in these patients.

The skin on the dorsum of one or both hands and arms was deeply burned in nine patients. These areas were the first grafted for reasons of comfort and early restoration of function. The relatively small areas of third degree burn on the faces were grafted as early as possible for cosmetic reasons. The back was burned deeply in six patients. Several of them also had burns of the hands and arms which were treated first. During the interval, the backs healed so rapidly that grafting was necessary in only one patient. Small areas of the scalp were allowed to heal spontaneously; larger areas were grafted. Exposed cartilage of the ear in one victim was saved by adequate soft tissue drainage. The legs of two patients were grafted.

Keloid has developed in the hands of the two patients mentioned above in whom there was loss of the graft. It has also developed in several small areas of the neck and chin as well as the larger areas of the back where spontaneous healing occurred. Elsewhere there has been satisfactory surfacing by successful skin grafting.

Function of the hands has returned slowly because of inability to splint the hand in the neutral position. Flexing the fingers put the open wounds on the dorsum under tension, and the patients could not tolerate the pain. There was also blanching of the tissue over the joints which increased the danger of further tissue necrosis and exposure of the extensor tendons and the joints. Therefore, the fingers were allowed to remain in extension and the wrist in a neutral or slightly dorsiflexed position until, at operation, they were put in a more nearly normal position. With complete healing, recovery of function has been hastened by supervised physiotherapy with the use of whirlpool baths and local massage. There is normal extensor function in the hand of the patient who had the direct abdominal flap over two exposed tendons.

COMMENT

The ultimate purpose of any method useful in the local treatment of burns is to protect from secondary damage all cells not destroyed by the heat. Therefore, the evaluation of the unorthodox method employed in this group of patients depends on determining whether the healing time was prolonged because the burns were neither débrided nor cleansed before the first dressings were applied.

The usual healing time of uninfected second degree burns is from two or three weeks, which was the same interval of healing in these patients. Examination of the wounds at the first and subsequent dressings revealed no destructive invasive infection. The destroyed epithelial debris was dry, and the contents of the intact blebs were sterile. The failure to débride the wounds initially did not delay the healing of the second degree burns in any measurable degree.

In the patients with both second and third degree burns, the surface remained free from active infection during the first two weeks. By the

end of two weeks, the areas of second degree burn were healed, while, in the immediately adjacent third degree areas, slough was separating. Staphylococci and the saprophytes flourished in the slough but did not invade the living tissues. Little exudate and no abscesses were found beneath the slough. The first graft was done on the twenty-third day. In one patient, exposed extensor tendons were found and salvaged by being covered with an abdominal flap on the twenty-eighth day. It is apparent from these observations that the wounds were free from invasive infection and that there was no measurable delay in carrying out the reparative procedures.

It seems reasonable to conclude from these observations, both on the second and third degree burns, that débridement and cleansing need not be part of the definitive treatment. Tissue resistance and general chemotherapy can be relied upon to prevent invasive infection. However, for success, an ointment gauze should be used to allow drainage into the overlying dressing. The surface must not be sealed by an impervious membrane or a harmful eschar. Precautions should be taken to reduce contamination by careless exposure of the wounds at the primary dressing and by two frequent subsequent changes.

The importance of the general nutritional state in the spontaneous healing of burned surfaces and the preparation of these surfaces for successful skin grafting cannot be overemphasized. Only by early skin grafting can large burned areas be covered and the development of contractures be avoided.

SUMMARY

The experiences with victims of the Boston night club fire treated at the Massachusetts General Hospital are described, and the evidence which led to the unorthodox method of treatment is presented. The dangers of invasive infection and harmful escharotics to cells surviving the heat are stressed. The value of reliance on tissue resistance, internal chemotherapy, and occlusive ointment gauze dressings in promoting early healing of second degree burns and in preparation for repair of third degree burns with skin grafts or flaps is emphasized.

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FREE TRANSPLANTATION OF THE NIPPLES AND AREOLAE

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THE purpose of this article is to give additional proof that free transplantation of the nipples and areola can be successfully performed. The method offers a distinct advantage over the usual types of mammary plasties in that the reshaping of the breasts is completed before any attempt is made to select the new sites for the nipples.

Numerous operations have been devised for reducing the size and improving the shape of the hypertrophied and pendulous breast. Simple amputation of the breast with complete disregard of the nipple is recorded as having been done in the early part of the sixteenth century. Amputation is inexcusable for the benign hypertrophied and pendulous breast.

Lotsch[6] and Martinez and Noel[7] were of the first to employ skin plastic operations for improving the appearance of the simple ptosed breast. Their technique consisted of various incisions of the skin about the nipple permitting it to be shifted to a higher position on the breast.

For the overly large pendulous breast, Mornard,[8] Lexer-Krashe,[5] Hollander,[3] and Passot[9] advocated a resection of the excess breast tissue, and at the same time an improvement of the shape. Of these, Passot's technique probably offers the best results. An incision is made around the areola, and a circular buttonhole incision is made at the newly selected site for the nipple. The skin above the nipple is undermined sufficiently to allow shifting of the nipple, intact with the gland tissue, to its new location. The redundant portion of the breast tissue with the overlying skin is then excised, leaving an incision to be closed along the submammary fold.

Joseph,[4] in 1922, was one of the first to advocate the two-stage operation for excessively large and pendulous breasts, since this method lessened the danger of necrosis of the nipple and areola. This operation consisted of a transfixation of the nipple with the mammary gland tissue to its new location in the first stage, and removal of the redundant breast tissue at a second stage.

The following year Axhausen[1] introduced his method of undermining the skin overlying the entire breast, permitting a free upward shifting of the breast with the nipple. The excess breast tissue was then removed from the medial and lateral aspects.

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Biesenberger,[2] in 1927, advocated his method of reducing and reshaping the breast by means of an S-shaped incision in the lateral portion of the mammary gland. The remaining breast tissue, with the nipple intact, was then rotated on itself to form a more conical shape.

Thorek,[10] in 1921, reported: "It is possible to disconnect completely the nipples and areolae from the subjacent beds and transplant them to a new position in the remodeled breast."

For some time I had wanted to attempt the free grafting of the nipples and the areolae, but the opportunity did not present itself until one and one-half years ago, when a negro woman was referred to me for complete removal of her breasts. Because of their tremendous size and weight she was unable to do any work. In addition, they caused her considerable discomfort. The patient voluntarily stated that it was absolutely immaterial with her whether or not the nipples were saved. This appeared to be the ideal case for first trying a free transplantation of the nipples and areolae.

CASE REPORTS

CASE 1.—R. F., a Negro woman, aged 34 years, was admitted to the John Gaston Hospital on May 18, 1942. Her chief complaint was very large breasts and backache (Fig. 1 *A*). The patient first noticed breasts increasing in size three years before admission. After removal of the uterus, both tubes, and both ovaries in 1940, the size of the breasts increased much more rapidly. For one year before admission to the hospital the patient had been unable to work because of the extreme weight and size of the breasts. If the patient was required to stand for any length of time, she had considerable pain in the upper part of her back and shoulders, as well as in the upper part of the anterior chest. When breasts were not supported, there was an intense itching of the nipples and areolae, together with a dull aching pain in the whole lower portion of the breasts.

The patient had always been well until she developed a pelvic inflammatory disease in 1940, for which she had a supravaginal hysterectomy and a bilateral salpingo-oophorectomy. Findings at operation were uterine fibromyomas, bilateral salpingitis of the left hydrosalpinx, left ovarian cyst, and bilateral ovarian atrophy. She began menstruating at the age of 14. Menses were twenty-eight-day type, six days' duration, and regular until about six months before the pelvic operation. The patient had been married ten years and had one pregnancy which terminated in a miscarriage in 1934. Physical examination was essentially negative for the breasts which extended down to the upper margin of the pubic bone. When she was in a sitting position, the breasts rested on the thighs. The skin of the supramammary region was very tight due to the extreme weight of the breasts. The areola of each breast measured about 3½ inches in diameter. If the breasts were allowed to hang, the nipples and surrounding skin became noticeably cooler.

Operative Procedure.—With the patient in a sitting position the new sites for the nipples and areolae were selected and outlined with brilliant green. A circular area of the desired size was outlined about the nipples which were to be transplanted. After the usual skin preparation, 1 per cent novocain infiltration was used as an anesthetic. With a very sharp scalpel, a near full thickness skin dissection was made at the new site for the nipple. This dissection was done as in obtaining a near full thickness skin graft, removing all the glandular portion of the skin, and leaving

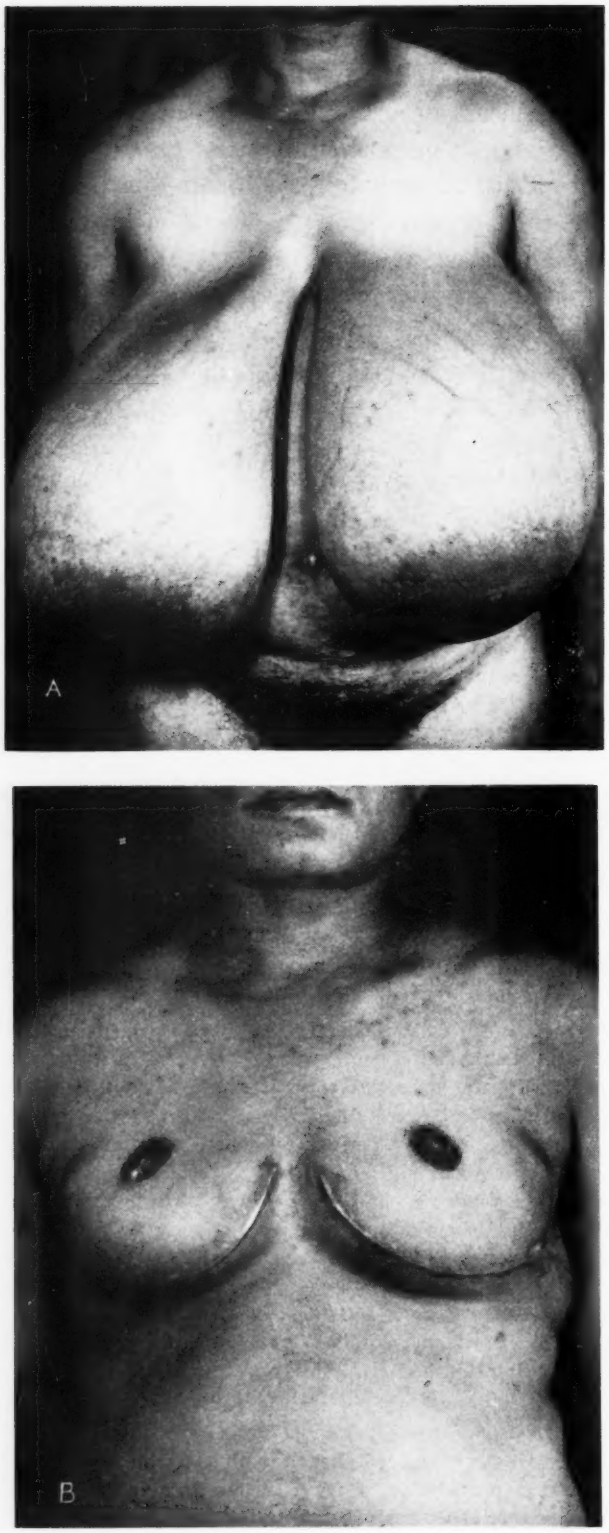

Fig. 1 (Case 1).—*A.* Extremely large pendulous breasts in a Negro woman 34 years of age. *B.* One and one-half years after partial amputation, reshaping of the breasts, and free transplantation of the nipples and areolae.

only a very thin layer of the dermis, at the same time being very careful not to expose the underlying subcutaneous and fatty tissue. It was thought that this would furnish a much richer bed to nourish the nipple and areola graft. Dissection of the areola was then begun at the periphery, care being taken not to include any of the subcutaneous or fatty tissue. As the region of the nipple was approached, the dissection was gradually made deeper in order to obtain some of the underlying smooth muscle tissue (Fig. 2 *A*). This was done hoping that there might be a return of function of the smooth muscle. The nipples and areolae were then sutured in place at their new locations. Four retention sutures were placed so that the graft would be evenly spread over the raw area (Fig. 2 *B*). A simple continuous suture of 4(o) Deknatel, black silk, was then placed around the periphery. The graft was sutured to the recipient raw area in a "quilting-like" manner, in order to insure immobilization and close contact (Fig. 2 *C*). This procedure was repeated on the opposite breast, after which an elastic pressure-immobilizing dressing was applied. The dressing was changed for the first time on the tenth postoperative day. There was a complete take of the grafted nipples and areolae.

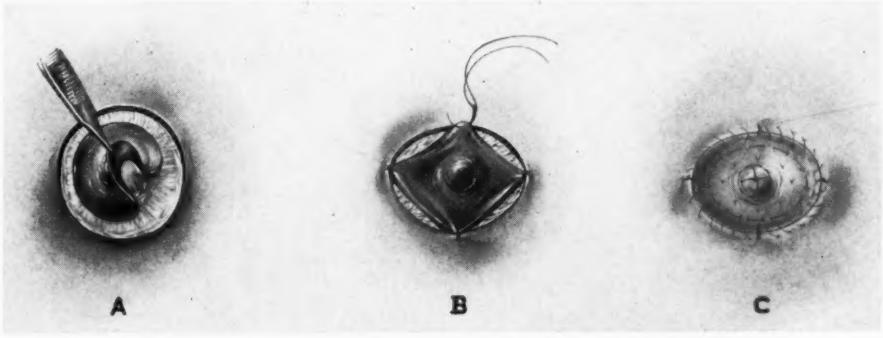

Fig. 2.—*A*. Illustrating the dissection of the nipple and areola including a portion of the smooth muscle of the nipple. *B*. First step in the application of the nipple and areola graft to its new location. Four retention sutures are used to insure an even distribution of the graft. *C*. Technique used in suturing the graft to its new site. A simple continuous suture is placed around the periphery. The central portion is sutured to the recipient raw area in a "quilting-like" manner.

Two weeks later the patient was again taken to the operating room. She was given a general anesthetic, and by two semicircular incisions above and under the breasts along the submammary fold, the redundant portion of the breasts was amputated. The remaining breast tissue was reshaped and held in place by several retention sutures of 00 chromic catgut. The skin margins were sutured together along the submammary fold. A pressure dressing was then applied over the breasts.

After the partial amputation and the reshaping of the breasts was undertaken, it was evident that the nipples had been grafted in too high a position on the breasts. This exemplified the disadvantage of transplanting the nipples before reshaping the breasts.

The patient had an easy, uncomplicated postoperative recovery. Incisions healed by primary intention without drainage. About one month after operation keloid scars began to develop in the submammary incisions. Three x-ray treatments were given with successful results. About three weeks after the operation small blanched areas began to appear in the areolae as a result of a loss of some of the brownish pigment. Six months later all the normal pigment had reappeared. There was a definite erection of the nipples on manipulation, which could only result from the contracture of the smooth muscle grafted with the nipples. There was also a return of normal tactile sensation of the nipples and areolae (Fig. 1 *B*).

The patient was last seen sixteen months following the operation, at which time she was well and steadily employed in a defense plant.

CASE 2.—Mrs. E. G., a white woman, aged 42 years, was admitted to the Hospital in December 1942, for correction of large pendulous breasts (Fig. 3 *A*). The patient first noticed the breasts being larger than normal at the age of 20. They had gradually, though steadily, increased in size since that time. The overweight and massiveness of the breasts caused her considerable discomfort and frequent backache. The patient had never had any serious illnesses or operations. She began menstruating at the age of 17. Periods were always irregular until she reached the

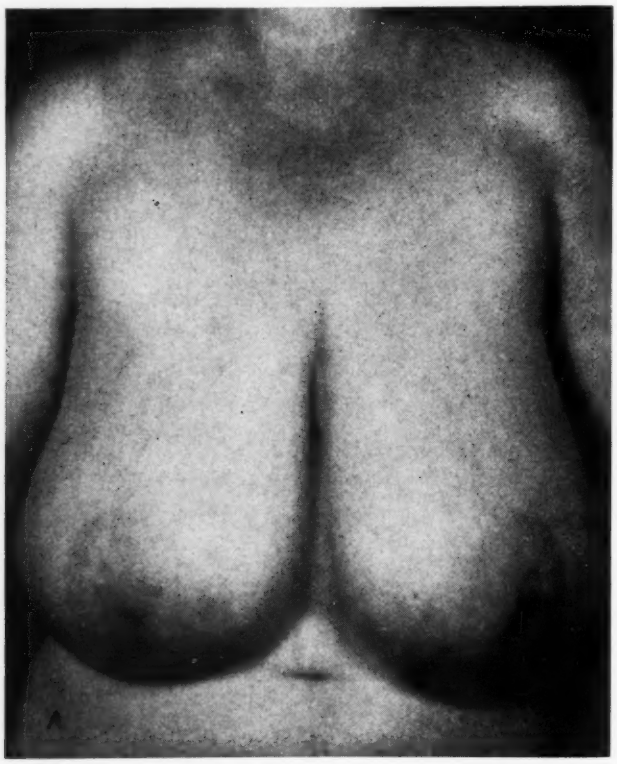

FIG. 3*A* (Case 2).—Large pendulous breasts in a white woman 42 years of age.

age of 32 years. Since that time they have been regular, twenty-eight-day type, four to five days' duration. During menses there was an uncomfortable sensation of fullness in the breasts, and the nipples were sore and tender, so much so that she often had to remain in bed. The patient had been married nineteen years, but was never able to become pregnant. Physical examination was essentially negative with the exception of a generalized enlargement of both breasts which hung down below the umbilicus.

Due to the successful grafting of the nipples and areolae in the previous case, it was decided that the entire procedure of reducing the size and reshaping the breasts, together with the free grafting of the nipples and areolae, could be carried out in one operation without interfering with the take of the grafts.

In estimating the amount of breast tissue to be removed, the size and shape of the patient's entire body was taken into consideration. The selected points of excision were outlined on the anterior and posterior surface of the breasts. These

lines were semicircular in shape and corresponded roughly with the submammary fold. The new sites for the nipples were selected only tentatively, as this cannot be accurately done until after the partial amputation is completed and the remaining breast tissue is reshaped.

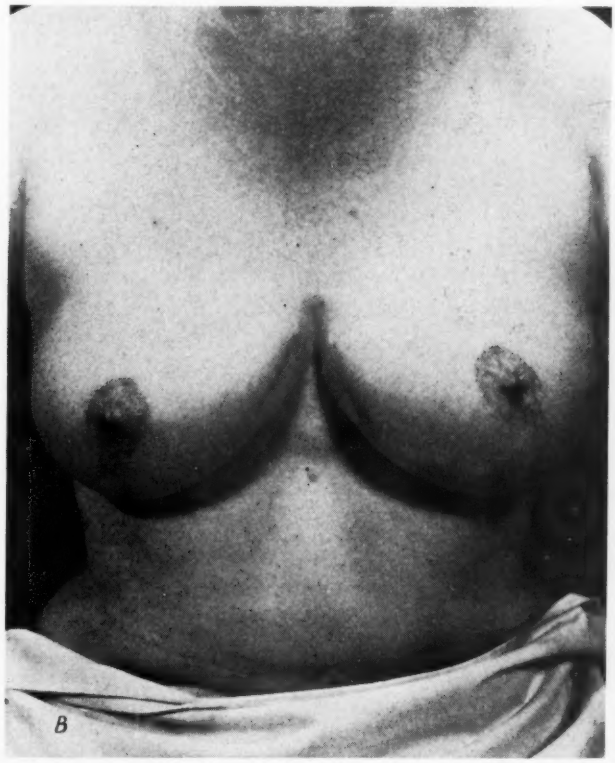

Fig. 3*B*.—Patient seven months following partial amputation of the breasts, reshaping of the remaining breast tissue, together with a free transplantation of the nipples and areolae, which was done in one operation. There is a definite elevation of the nipples.

Operative Procedure.—The nipples and areolae were dissected under local anesthetic using 1 per cent novocain. This was done to decrease the time of the general anesthetic used in the amputation of the breasts. Dissection of the areolae was made as in obtaining a full thickness skin graft, being careful not to include any subcutaneous or fatty tissue. Near the nipples the dissection was gradually made deeper in order to obtain some of the smooth muscle tissue (Fig. 2 *A*). The nipples were carefully wrapped in gauze wet with normal saline solution to prevent drying-out of the grafts. Care was taken that the normal saline solution was not hot, nor even warm, as it might cause a coagulation of the blood in the arterioles and venules. Grafts, wrapped in the gauze, were clamped to the covers of the instrument table with towel clips as a precaution against their being discarded. The patient was then given a general anesthetic of cyclopropane. Elliptical incisions were made in the skin on the anterior surface of the breasts corresponding with the underlying submammary fold. The breasts were elevated and similar incisions were made on the under surfaces, just above the submammary folds. Through these incisions the redundant mammary tissue was removed. With the patient in a near-sitting position the remaining breast tissue was reshaped and held in place with several

retention sutures of 00 chromic catgut. The two raw surfaces of subcutaneous and fatty tissue underlying the skin margins were approximated with 00 plain catgut. Skin closure was made with interrupted No. 1 Deknatel and a continuous

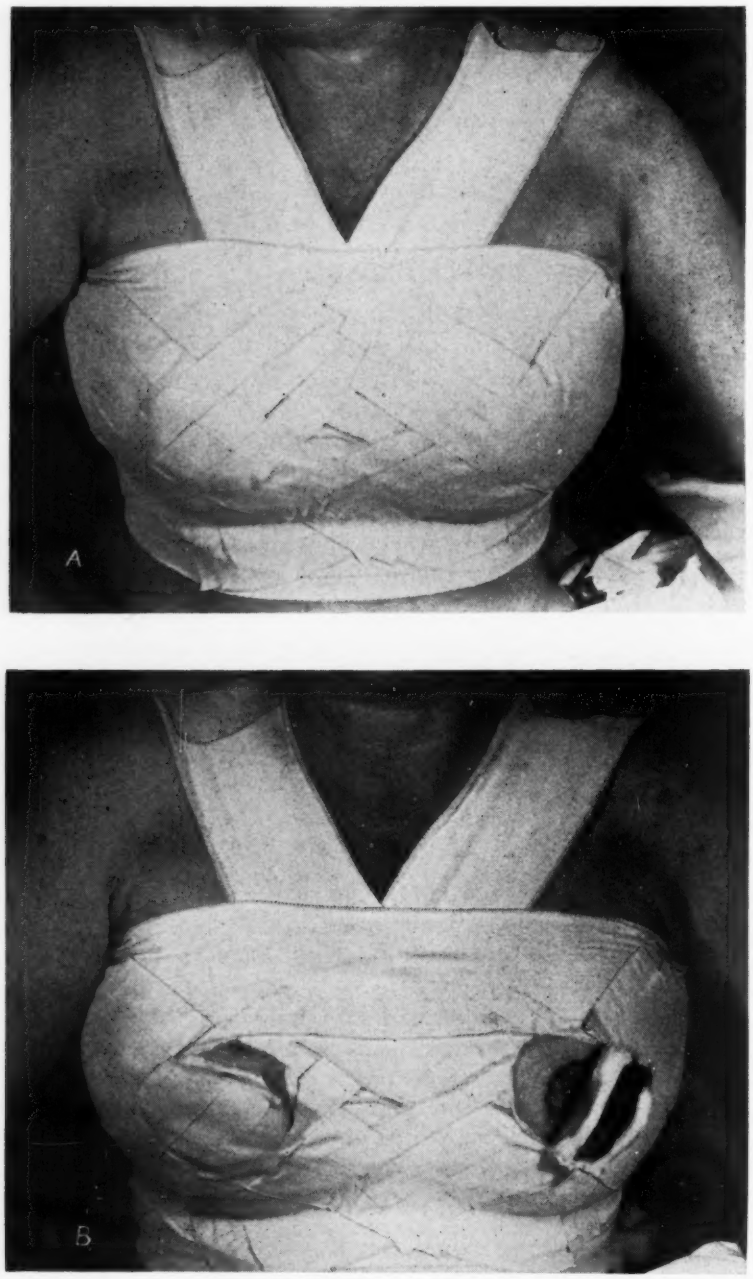

Fig. 4 (Case 2).—*A*. Completed elastic immobilizing dressing. *B*. Dressing partly removed to illustrate the different layers applied in the following order: Xeraform gauze, dry gauze, rubber sponge, dry gauze and elastoplast.

suture of 3(o) Deknatel black silk. After the reshaping of the breasts was completed, and while the patient was still in a near-sitting position, the new sites for the nipples were selected and outlined corresponding in size to the nipple grafts. The circular areas of skin were dissected carefully, leaving only a thin basal layer of the dermis, and being very careful not to expose the subcutaneous and fatty tissue. After complete hemostasis was obtained, the nipple and areola grafts were sutured in their new location, as described in Case 1 (Fig. 2 *B* and *C*).

An elastic pressure bandage was applied in the following manner. Three layers of 3 per cent Xeraform gauze were placed immediately over the grafts and the incisions of the submammary folds. Dry gauze, 1 cm. in thickness, was next applied, then a rubber sponge of the same thickness. The central portion of the sponge which was to lie directly over the nipple was "saucerized" as a precaution against exerting too much pressure on the nipples. The rubber sponge was covered over with a thin layer of dry gauze. The dressing, at this point, was held in place with a few strips of plain adhesive. Both breasts were completely covered with a thin layer of dry gauze. Three-inch elastoplast was used to immobilize the breasts, and to help maintain their proper shape, obliterating any possible dead spaces, and to assure an even distribution of pressure throughout (Figs. 4 *A* and 4 *B*). The importance of the proper dressing cannot be too strongly emphasized, as the success of the operation depends largely upon its application.

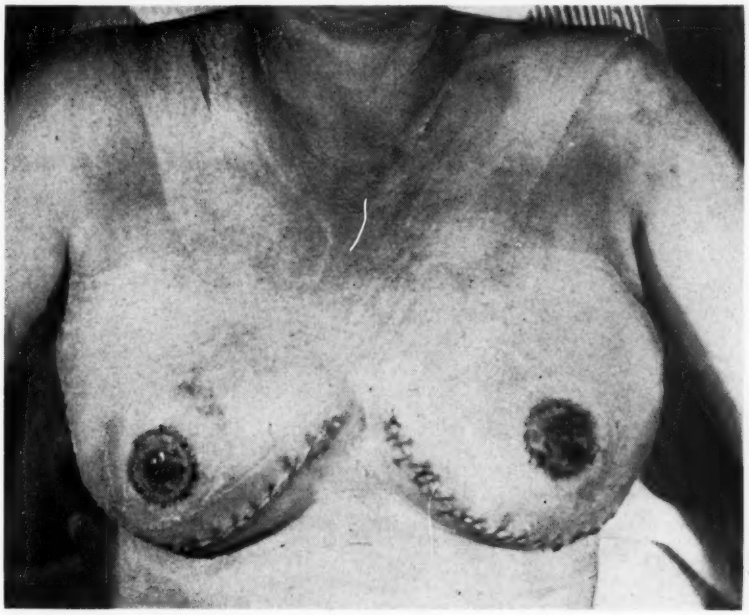

Fig. 5 (Case 2).—Appearance of the nipple and areola grafts at the first dressing, ten days postoperatively. There was a complete take of the grafts.

The dressing was inspected daily to be sure that proper pressure was maintained, and that there was no odor or drainage present. Practically the only pain of which the patient complained was a backache in the lumbar region. This pain disappeared immediately after she was allowed to sit up.

The first postoperative dressing was done on the tenth day. There was a complete take of the nipple and areola grafts (Fig. 5). All sutures were removed, and an elastic pressure bandage was reapplied (Fig. 4 *A*).

The patient left the hospital on the thirteenth postoperative day. A pressure bandage was worn for two weeks, after which sufficient pressure and immobilization were maintained by a well-fitted brassiere. She was last seen seven months following the operation. The breasts were well proportioned in size and shape and were smooth and firm throughout. There were no areas of tenderness or soreness. Three months after operation, the patient began to have a return of normal tactile sensation of the nipples and areolae. They were quite normal in appearance. The nipples were definitely elevated above the surrounding areola tissue. Following a slight massaging there was a definite erection of the nipples and a constriction of the areolae tissue immediately surrounding them (Figs. 3 *B* and 6). This should definitely prove that there is a return of function of the grafted portion of the smooth muscle of the nipple.

Fig. 6 (Case 2).—Close-up photograph, seven months postoperatively, of the grafted nipple and areola on the newly shaped breast, illustrating the normal appearance of the nipple and areola after free transplantation.

SUMMARY

Free transplantation of the nipples and areolae is recommended for the correction of the extremely large and pendulous breasts. The removal of the redundant mammary tissue, together with the complete reshaping of the breasts and the free grafting of the nipples and areolae, can be accomplished in one operation. After the proper form and shape of the breasts has been obtained the selection of the new sites for the nipples may be more accurately made. A small portion of the smooth muscle of the nipples should be included in the grafts so that the nipples

will be elevated above the areolae, giving them a normal appearance. It is thought that nipple and areola grafts should take with the same relative assurance as the usual free full thickness skin graft.

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SIMPLIFIED METHOD OF ROTATING SKIN AND MUCOUS MEMBRANE FLAPS FOR COMPLETE RECONSTRUCTION OF THE LOWER LIP

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DEFECTS of the lower lip result from inflammatory or degenerative processes, as advanced carcinoma[1, 2] and extensive ulcerations (noma); or traumatisms from burns[3] or other accidents.[4, 5] That reconstruction of these defects has been a surgical problem for many years is evidenced by the fact that according to Pierce and O'Connor,[1] over sixty-five methods and modifications of repairing complete or partial defects of the lower lip have been described in the literature. According to Martin,[6] von Bruns,[7] as early as 1859, had found thirty-two methods described by fifty-two authors. That there have been so many different methods for the correction of this defect is indicative of the inexpedience of any one method. This fact should decry, on the one hand, the advancement of a new technique which may be only as good as others previously advocated, and yet, on the other hand, should be a stimulant to the development of a technique which fulfills satisfactorily all surgical requirements.

Cheiloplasty for carcinoma of the lower lip, one of the oldest operations known, has been practiced since the days of Celsus (born about A.D. 25).[6] He is generally considered the originator of a method, the principle of which is still adhered to today—V-shaped incision and modifications including horizontal incisions from the angles of the mouth and along the lower edge of the mandible forming two lateral flaps of the cheek. According to Foman,[8] the Hindus utilized rotating flaps from the adjacent tissues to rebuild a defect of the lip; this later became known as the Indian method. Tagliacozzi is accredited with the first description of a technique using flaps from the arm (1597).[9] Chopart,[10] in 1785, reported the use of advancing flaps from the neck and chin for this purpose. Most of the operations advocated today are modifications of procedures, the basic principles of which were recognized in the early nineteenth century.

Bernard[11] and Burow and Saemann,[12] in 1853, devised an operation in which full-thickness triangles were removed from the upper lip and discarded. The lower lip was then built by loosening and pulling the sides of the cheeks to the midline over the mandible. This procedure was modified by Steward,[13] in 1910, and Martin,[6] in 1932.

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In 1877, Estlander[14] proposed a procedure which is one of the recognized methods of lip reconstruction today. A V-shaped incision is made. A similar defect only one-half the size is outlined at the outer border of the corresponding upper lip and excised completely, excepting the tissue where the coronary artery of the lip is located. The upper triangle is then turned down into the lower lip and sutured. In 1936, Padgett[15] modified this operation by bringing the outer part of the lower lip to the center to form the middle portion of the lip. The outer part is repaired from the upper lip flap. There have been innumerable modifications of the Estlander operation.

An extensive lower lip defect is usually reconstructed by some form of pedicle transplant, sliding,[16] rotating,[17] or advancing.[10] These transplants may be rotated from the tissue above together with a portion of the upper lip, they may be rotated from tissues beneath and lateral to the chin upward to rest on a buttress of tissue, or they may be rotated from the tissue above and lateral to the upper lip with the pedicle attachment incorporating a portion of the upper lip. In most methods of rotation flaps the necessity of a lining for the pedicle is ignored and frequently the mucous membrane lining the lips is overlooked. It is not unusual for the surgeon attempting reconstruction to underestimate the amount of tissue necessary to obviate the possibility of subsequent tightness of the lips. Consequently, a foreshortened, noticeably tight lip, which permits drooling, invariably results.

Sliding flaps, commonly fashioned from the tissues of the cheek lateral to the defect, are usually outlined by parallel incisions from the defect backard to the region at the anterior border of the ramus of the mandible. These flaps are, of course, as wide as the defect of the lip. This method is objectionable because it produces a tight lip which often breaks down because of the great tension. It is not only cosmetically undesirable but also functionally unsatisfactory; it narrows the orifice of the mouth proportionately, and makes the insertion of artificial dentures, when necessary, impossible.

There are numerous varieties of advancement flaps.[1, 6, 19, 19a] These might appear to be ideal from a cursory glance of the diagrams illustrating their formation. However, only casual study of these illustrations is necessary to realize that in most instances pedicle flaps cannot be fashioned and made to heal to conformity. Here, again, the common criticism is the resultant foreshortened lip and the failure to include the mucous membrane lining. Not only are there associated residual lateral defects following reconstruction in this way, but good functional result of the new lip is doubtful.

Occasionally, reconstruction of massive defects of the lower lip by the use of tube pedicle transplants from distant regions has been advocated.[18, 20, 21] Because the lip consists of two layers of skin with no

intervening muscle, repair according to this method gives a flabby lip, which is not good cosmetically. Then, too, the color and texture of the facial skin is only simulated by skin from the face, the forehead, or the mastoid region. The texture and color of skin taken from distant areas is almost uniformly at variance with facial skin. This type of repair probably should be resorted to only in those instances in which facial tissue is not available.

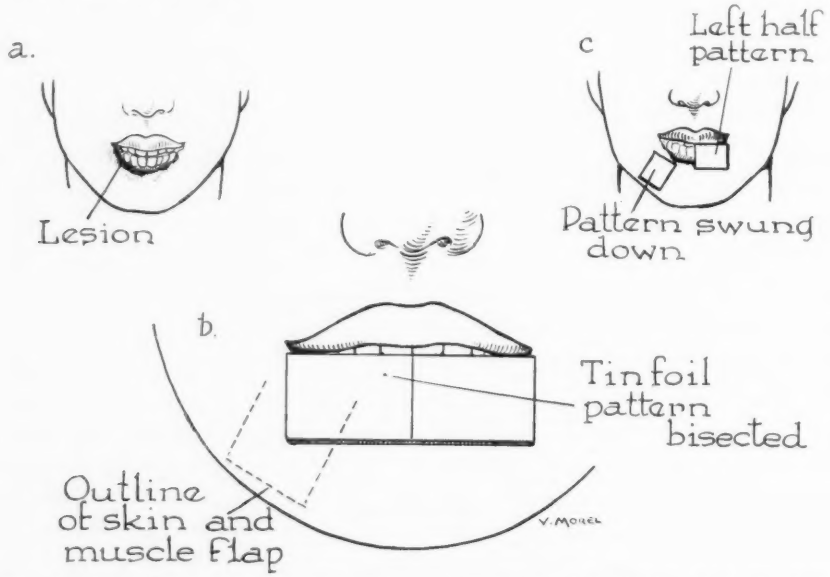


Fig. 1.—Drawing illustrating the placement of the tinfoil pattern into the defect, showing the location which the bisected half of the pattern assumes when it is shifted into its downward position preparatory to outlining the flap. Insert *a* shows the extent of defect and insert *c* shows the bisected pattern on the right swung down into position for outlining flap.

The following technique embraces simplicity and a satisfactory cosmetic and good functional result. Repair is accomplished by a combination of advancement flaps of both skin and mucous membrane. First, a pattern of the defect of the lower lip is made (Fig. 1). This pattern is then bisected, as only one-half the defect is reconstructed from its respective side. From the proper half of the bisected pattern an area of skin lateral and slightly inferior to the defect is outlined, identical in size and shape to the respective half of the bisected pattern. The pattern, anchored at its extreme lateral and upper border, is so formed that it may be swung downward and back to its normal position. After the pattern has been swung back and forth a sufficient number of times to insure the surgeon that the proposed flap is large enough to cover the defect, the margins of the pedicle are outlined with indelible ink or dye (Fig. 2). Following the pattern designed in this manner, the surgeon dissects the pedicle through skin, fat, and muscle, taking care not to penetrate the underlying mucosa. The flap is so designed that

it permits the incorporation of fibers from the triangularis muscle, thus imparting animation to the reconstructed lip and reflecting minimal disturbance in innervation and muscle function. After the pedicle

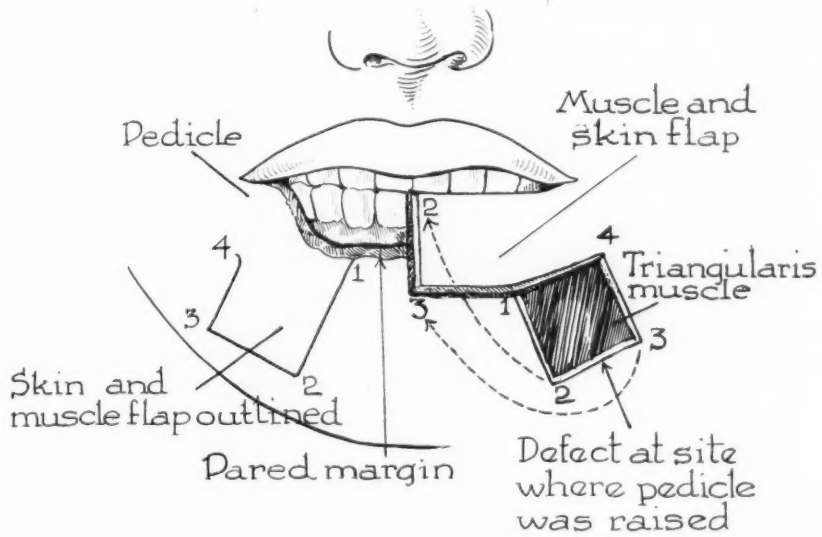


Fig. 2.—Drawing showing the flap outlined on the right and the flap dissected up on the left to include skin, fat, and a portion of the triangularis muscle. The flap on the left has been swung up into its proper position for its incorporation with the mucous membrane in reconstruction of the lip.

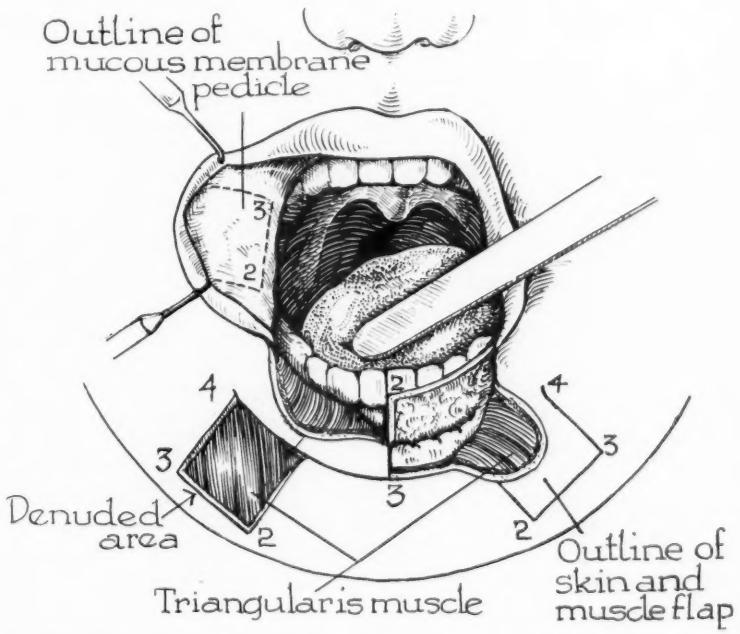


Fig. 3.—Drawing showing the outline of the mucous membrane flap over the buccal mucosa of the cheek on the right. The mucous membrane flap which was dissected up and advanced forward on the left is clearly shown. The skin and muscle flap on the right have been raised and brought into an upward position; that on the left is merely outlined.

has been raised and shifted forward into the defect and found to be adequate, it is wrapped in moist saline gauze. The same pattern used for outlining this skin and muscle flap is then carried inside the mouth where the upper and outer point is held fixed again, and in the same

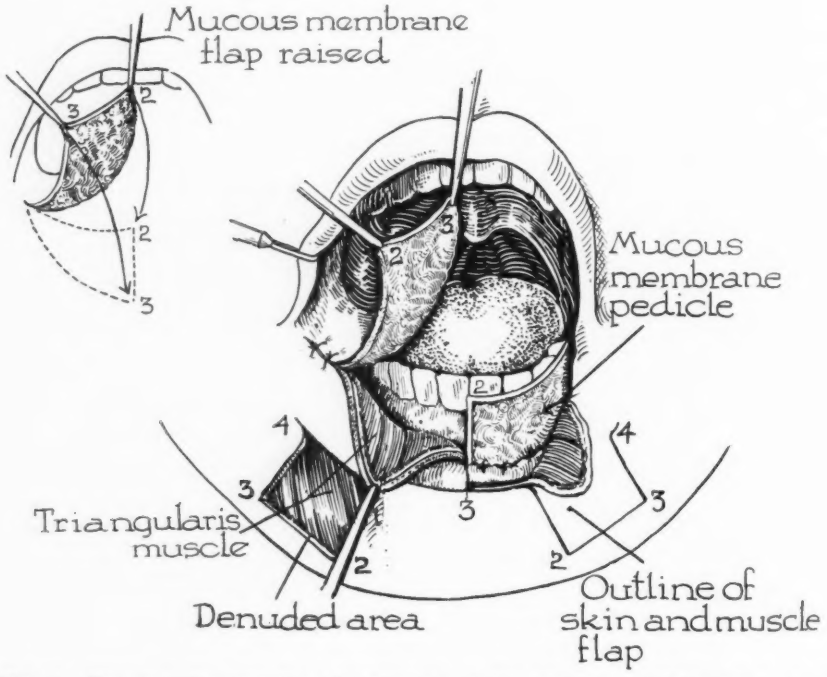


Fig. 4.—Drawing showing the advancement of the mucous membrane flap on the right cheek as it comes forward to join the skin and muscle flap. The mucous membrane flap on the left has already been advanced for the reception of the skin and muscle.

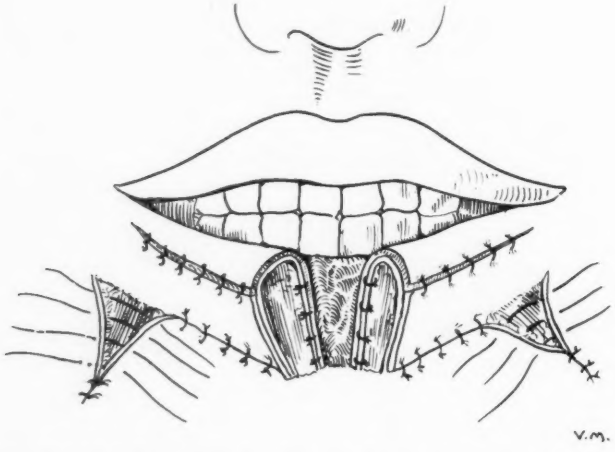


Fig. 5.—Drawing showing approximation of skin and muscle flap with the mucous membrane flap on either side. It also demonstrates the method of drawing the mucous membrane flap over the upper margin of the reconstructed lip where it forms the new vermilion border.

manner an area of mucous membrane identical in size and shape is raised and brought forward into the defect to form the lining of the lip (Fig. 3). The mucous membrane flap differs from the skin flap in only two essentials: it is not so thick and it is slightly wider. The purpose of this discrepancy in width is to enable the surgeon to bring the extra portion of mucous membrane over the upper border of the skin flap and

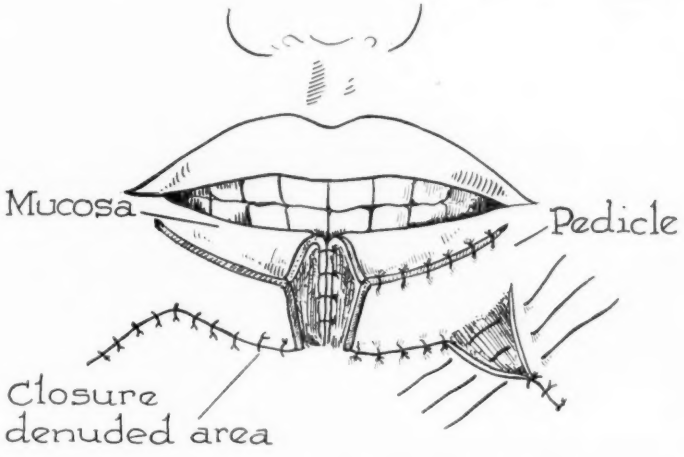


Fig. 6.—Drawing showing attachment of each composite flap with the other as they are joined in their final approximation to complete the newly formed lip.

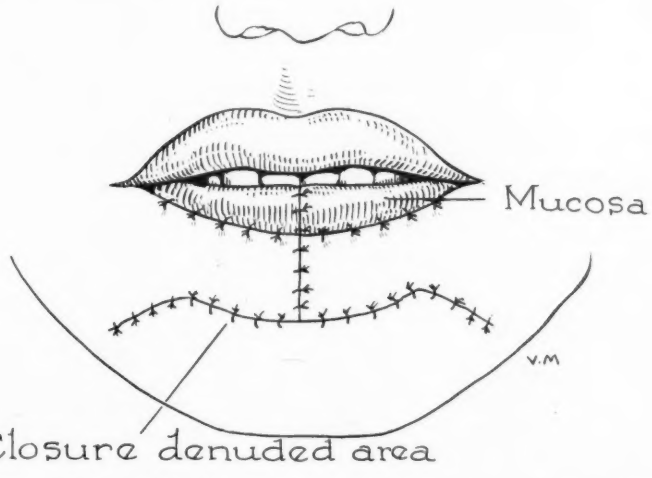


Fig. 7.—Drawing illustrating the completion of the reconstruction.

to suture it to the outer margin of the flap in such a way that it forms a covering for the upper border of the skin flap. This provides the vermilion border of the lip. Great care is taken to avoid injury to the Stensen duct. Following the dissection of the mucous membrane flap and its rotation into its anterior forward position, the defect is closed

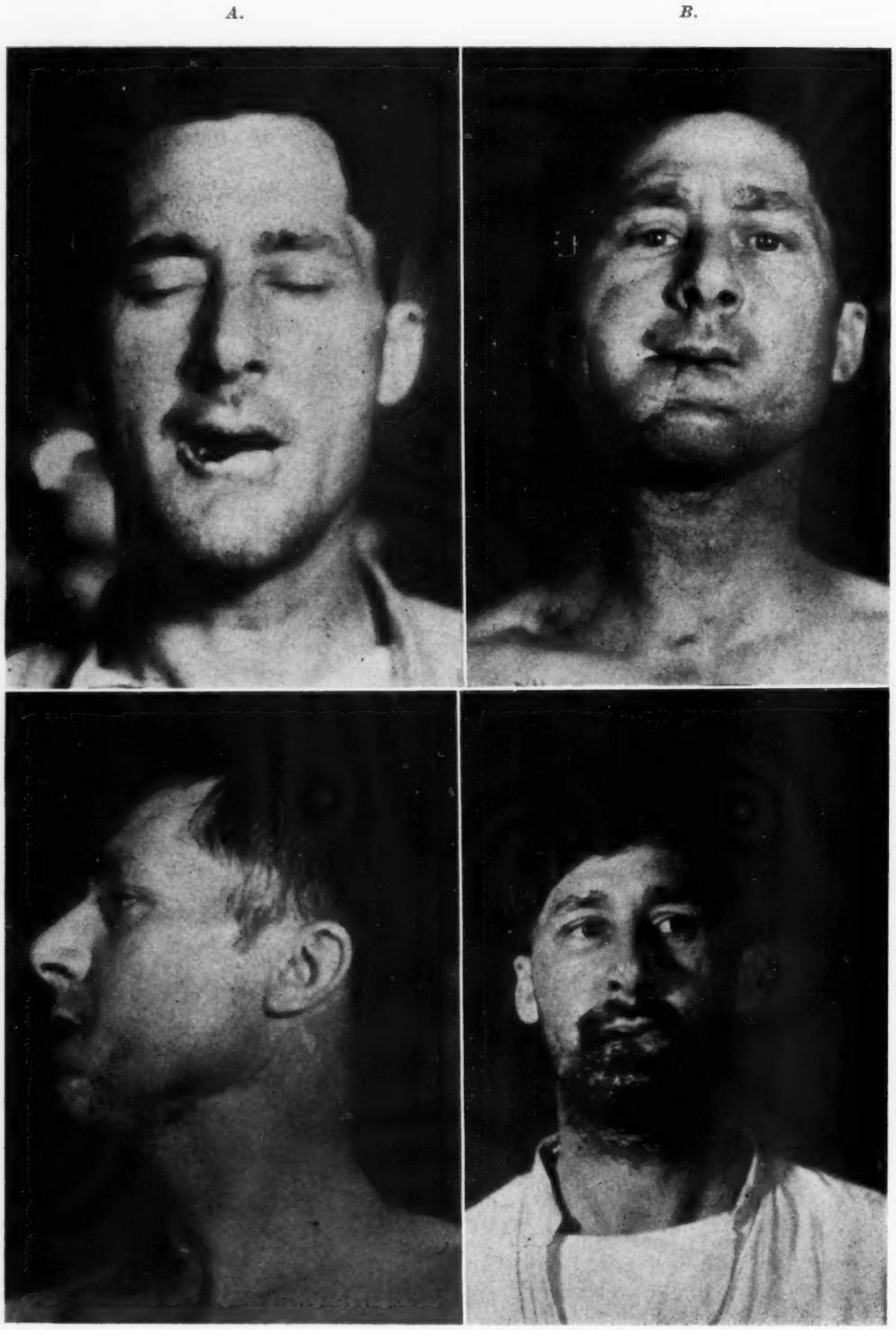


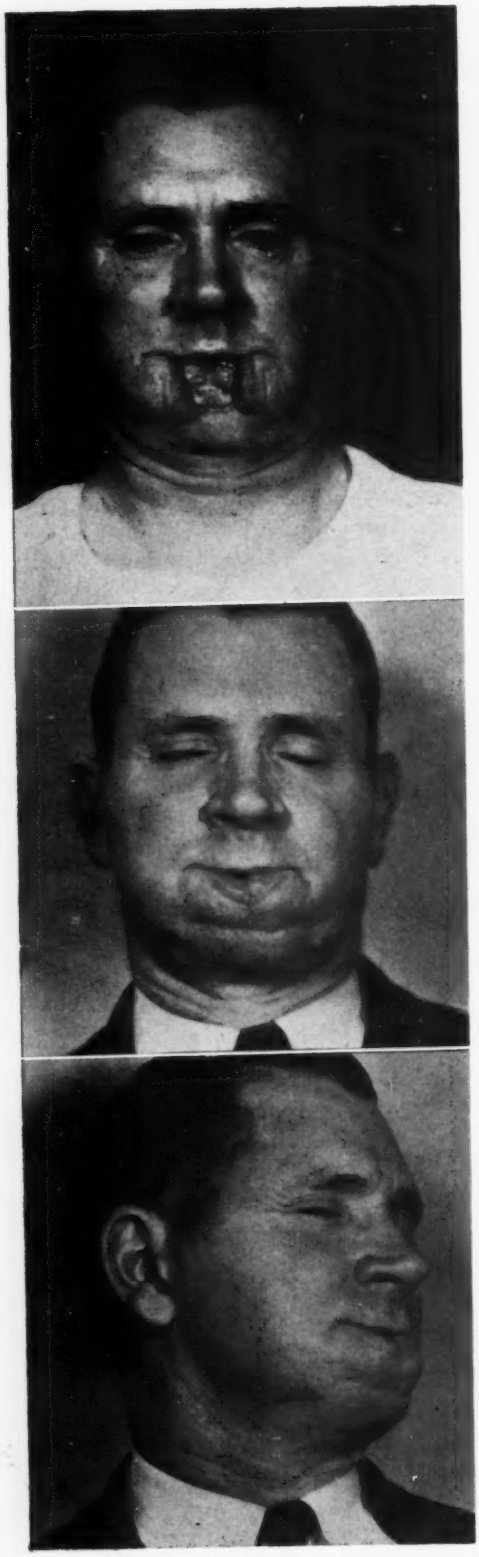
Fig. 8.—*A*, Photograph showing extensive carcinoma around the right half of the lower lip. *B*, Photograph taken ten days after operation. Procedure designed to remove all carcinoma and to reconstruct completely the lower lip at the same time. *C*, Lateral view taken ten days following operation. *D*, Photograph taken approximately six weeks following operation. Although the details of the lip are obscured by the beard, one can see that the lip has undergone considerable relaxation and the tissues are softer and under less tension at this time.

by direct approximation (Fig. 4). If there is any apparent shortness in the length of the mucous membrane flap, it may be necessary to adjust the base of the pedicle. If the dissection has been carefully carried out and all measurements accurately followed, the mucous membrane flap will fall into apposition with the skin flap so that they adhere in a normal manner and the upper border of the skin flap will be adequately covered by the excess of mucosa (Fig. 5). This represents the reconstruction of one-half the lip defect. When necessary, for complete reconstruction of the lower lip, the identical procedure may be carried out on the opposite side.

A. *B.*

Fig. 9.—*A*, Photograph showing defect resulting from removal of squamous carcinoma of the lower lip. *B*, Photograph taken approximately six weeks after complete reconstruction of the defect of the lower lip.

The defect inside the mouth, which should be sutured first, is closed with little or no difficulty by means of interrupted sutures of small black silk or 0000 silkworm gut. This line of closure continues along the entire inferior border of the newly formed mucous membrane flap (Fig. 4). The skin flap is then brought up into its position where it serves to reconstruct part of the defect of the lower lip, and the resulting defect lateral to the skin flap is closed by interrupted sutures of No. 1 black silk (Fig. 5). The flap usually will remain in place without tension.



A.

B.

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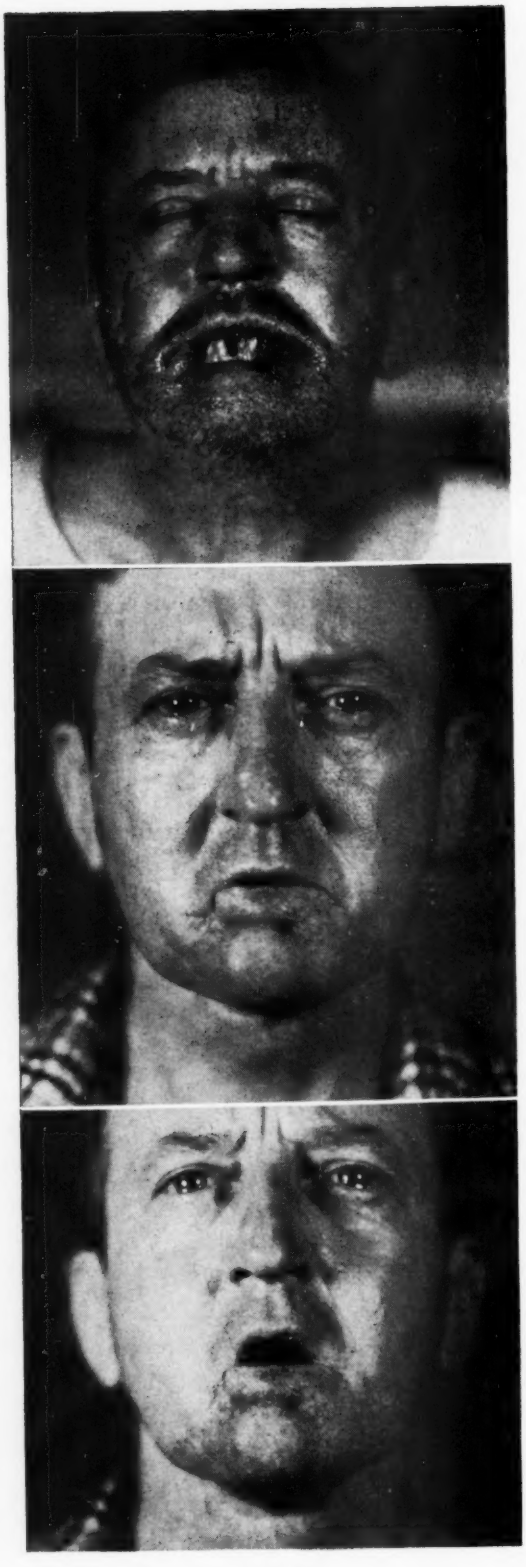
Fig. 10.



A.

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C.

Fig. 11.

(For legends see opposite page.)

Approximation of the inferior margin of the skin flap with the margin of the defect is then carried out with interrupted sutures of 0000 silkworm gut and an occasional suture of small black silk for tension. If this procedure is carried out accurately and meticulously there will be no tightness, shortness, or tension (Fig. 6). The excessive mucous membrane comes over the upper margin of the skin borders of the skin flap to form an entirely satisfactory vermilion border (Fig. 7). Two deep retention sutures of No. 50 white cotton are taken to hold the two skin flaps in close apposition in the midline. Other sutures of 0000 silkworm gut are added as interrupted ones. Because of the danger of infection in this type of wound, a small rubber dam drain is inserted through a stab wound made in the skin below the reconstructed lip and carried up to the inferior margins of the new lip by blunt dissection with curved scissors. This is left in place for forty-eight hours. Because this type of wound is subject to excessive contamination and because of the possible development of Vincent's angina, except when contraindicated, a prophylactic dose of neoarsphenamine intravenously is routinely administered. An additional 5 per cent solution of neoarsphenamine in glycerin is applied three times daily along the suture line.

This procedure has been carried out on twelve patients. The cosmetic results have been uniformly good, the functional results gratifying in all twelve cases. It is significant that in all of these patients there has been a noticeable absence of tightness or shortness of the lips and in no instance has a patient complained of drooling.

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Fig. 10.—*A*, Defect of the lower lip resulting from extirpation of the carcinoma. *B*, Photograph taken approximately two months following reconstruction of defect of the lower lip. *C*, Lateral view of reconstructed lip taken approximately six weeks after time of reconstruction.

Fig. 11.—*A*, Defect of lower lip following extirpation of squamous cell carcinoma. *B*, Appearance of the lip approximately six months following reconstruction. *C*, View showing the ability of the patient to obtain good open bite following this reconstruction.

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Editorial

A Plea for a Campaign to Reduce Burn Hazards

THE value of educational campaigns, fostered by insurance companies and other agencies, designed to familiarize the general public with health and safety hazards and to instruct in methods of eliminating these, has long been appreciated. As a result, the mortality rate in certain medical and surgical conditions has been appreciably reduced. The effects of such campaigns may be seen in two general groups: (1) that showing diminished mortality rate in proportion to the effort expended—as seen in campaigns against appendicitis; (2) that showing slight decrease in mortality rate regardless of effort—as demonstrated in campaigns against poliomyelitis.

Strangely enough, the one surgical condition which would reflect an astounding reduction in mortality rate as the result of a well-directed educational campaign has probably received less consideration than any other. Burns, because of their origin, lend themselves to this potential decrease in mortality rate. The relative importance of two similar programs, one directed toward poliomyelitis and one toward burns, becomes apparent when statistical figures are considered. During the period 1930 to 1940, the greatest annual death rate from poliomyelitis throughout the United States was 2,096. During the year 1942, the total number of cases of poliomyelitis in the United States was 4,193. Yet each year in the United States there is a death rate from burns which is practically twice as great as the actual number of cases of poliomyelitis. It is astounding, when one considers these figures, that a campaign designed to teach avoidance of common hazards responsible for accidental burns in everyday life has never been adequately undertaken. Such a program, properly presented and frequently reiterated, would unquestionably lower the incidence of burns to an amazing degree.

All burns are accidental in so far as the patient is concerned and, for this reason, lend themselves to a reduction in incidence provided certain hazards are removed. Proof of this is found where educational programs have been responsible for the enforcement of laws designed to remove hazards responsible for automobile accidents. A similar reduction in the incidence of burns would surely follow a program designed to focus the attention of the public on the necessity of removing certain common hazards. The importance of a program such as this becomes apparent when one realizes that approximately 8,000 lives are lost annually in the United States as the result of burns. Burns now occupy third place

as a causative factor in the production of accidental deaths in this country, being surpassed only by automobile accidents and falls.

Children are constantly brought into hospitals for the treatment of burns which result from the upsetting of pots containing hot water, scalding foods, or drinks of various sorts. A child reflects a natural instinct when he grasps the handle of a pot to peer into its contents. Mothers are aware that their children are inquisitive, yet they seldom visualize the possibility of serious accidents which this quality can cause in their own kitchens. Full realization of this possibility should result in mothers' refusal to let children go into kitchens. Some mothers will contend that this is an impossible prohibition, stating that one cannot keep children out of kitchens, but I know from experience that it is possible to enforce such a household restriction. With a conscientious amount of instruction it is amazing to find children stopping short at the kitchen door and making no effort to go into forbidden territory. How much better to exercise a little effort toward a program of this sort than to experience the heartaches of watching a seriously burned child who may even lose his life as the result of a burn from hot fluid or food. Within the past three weeks, three such cases have been presented for treatment on one service in the city of New Orleans, indicating the relatively high incidence of burns from this cause.

Every parent knows that a flimsy garment becomes a flaming torch when placed in contact with an open radiant heater and yet each year scores of helpless children (and adults) are presented for treatment with burns which resulted from this sort of thing. The obvious answer is thoughtlessness and lack of caution on the part of busy parents. A year-in and year-out program designed to remind parents of this hazard would do much to reduce the incidence of this class of burns. Another hazard equally as obvious is that of boiling water in open tubs. Every parent knows the danger of this and yet each year many children are brought to hospitals with severe burns resulting from contact with hot water in tubs. Many of these children plunge downward in attempting to investigate the contents of the tubs; others stumble and fall into the steaming water; others are placed in hot water by their own mothers, who assume that the water is of proper temperature. The danger of these hazards properly emphasized and constantly reiterated would do much in lessening burn mortality from these causes.

An educational program to reduce the incidence of burns should direct especial effort toward obtaining strict enforcement of laws prohibiting the sale of fireworks. The obvious need of this prohibition requires no discussion. The sale of this type of explosive to children is against any vestige of common sense and should be strictly forbidden at all times.

Numerous other instances of fire hazards, equally as obvious or insidious as the few common ones already listed, could be incorporated into a comprehensive educational campaign to eliminate some of the more

common causes of high mortality from burns. Such a survey, with adequate discussion of their relative importance in the production of such an alarming mortality rate, could not fail to effect a tremendous reduction. A perennial program which would continue to parade these facts before the general public until their hazard values were established would serve as a driving force in effecting still further reduction in the death rate from burns and in establishing a determination in the minds of countless parents and relatives to show a continued reduction in burn mortality.

The problem of reduction in the mortality rate by an educational program like that proposed is of definite concern to all plastic surgeons. All possible effort toward the development of such a campaign should be exerted by those concerned in advancing plastic surgery because the adequate care of burns embodies so many fundamentals of this specialty.

—*Neal Owens, M.D.*
New Orleans, La.

Book Reviews

Treatment of Burns. By Henry N. Harkins, Henry Ford Hospital, Detroit, Ed. 1. Pp. 47, with 120 illustrations. Springfield, Ill., 1942. Charles C Thomas, Publisher. $6.50.

This is a comprehensive monograph embracing the whole subject of burns. The physiologic aspects brought about by the extensive loss of the surface covering is well discussed. The many methods of local treatment of the burned area are discussed in detail. The tannic acid method, originated by the late Dr. Davidson of the Henry Ford Hospital, is given special prominence—perhaps more than current trends in burn treatment justify. The general management of burns with reference to the replacement of lost fluid and plasma is emphasized, and practical guides, for the determination of the amount of plasma to be administered, are outlined. The nutritional problem presented by patients surviving extensive burns warrants a broader discussion than that accorded this phase of the problem by the author. The plastic management of the late cases is well covered. Unusual complications attending burns, such as bleeding duodenal ulcer, are dealt with at length. This is a valuable treatise on the whole problem of burns and the monograph can be recommended enthusiastically as an important source book.

Plastic Surgery of the Breast and Abdomen Wall. By Max Thorek. Pp. 446, with 458 illustrations. Springfield, Ill., 1942. Charles C Thomas, Publisher.

This book deals essentially with two conditions: (1) abnormal or pendulous breasts and means of surgical correction and, (2) lipectomy for the pendulous adipose abdominal wall. The author has approached the first subject from a very philosophic point of view. Racial and anthropological differences in breast conformation are discussed. The many operations which have been devised to correct breast deformities are reviewed in detail. The illustrations are particularly good. All surgeons interested in the plastic reconstruction of pendulous breasts will wish to acquaint themselves with this book.

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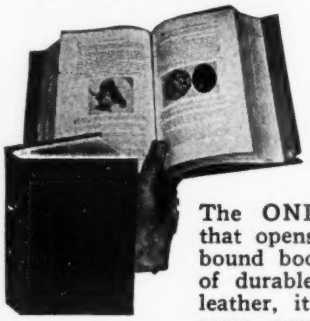

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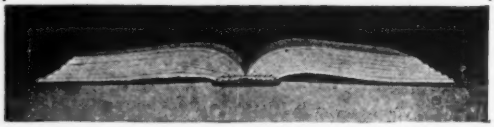

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CARDIOPULMONARY DISTURBANCES ASSOCIATED WITH MEDIASTINAL DISPLACEMENT AFTER PNEUMONECTOMY.
By Herbert C. Maier, M.D., Sc.D.(Med), Chicago, Ill.

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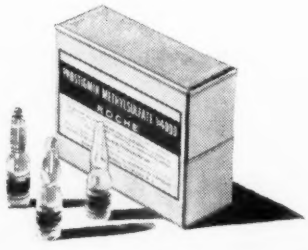
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